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Engineering Practice as Applied to the Fueling Equipment of Power Houses.

BY HARRY P. COCHRANE.*

In the manufacture of any product the primary object is production with the least expenditure of money, due importance being given to the reliability of the product.

The operating expense account of any plant depends a great deal upon its mechanical equipment.

For many years the energy of power station engineers was mainly devoted to perfecting the arrangement of engines, generators and electrical apparatus, often neglecting the more important, though less showy, boiler-room equipment. A larger percentage

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of saving can be made by a proper attention to the design and operation of the boiler room than in any other department of the station.

The cost of power is an important factor, sometimes amounting to more than all other operating costs combined, and depends upon the cost of fuel; the cost of fuel in turn, upon the purchase price and method of handling.

The method of handling depends a great deal upon local conditions. Whether an outlay for mechanical handling is justified depends upon the size of the plant, but, sometimes, the matter of convenience or space may be a factor.

The transportation of coal from stock to ash heap via boiler room cannot be done in one place the same as in another location, with the same degree of efficiency and at the same cost. The location and the surroundings are the controlling factors.

Is expenditure for mechanical handling justified, and will the amount to be saved show as a profitable return on the investment?

Some plants are so small and convenient that one man can care for the boilers and do the firing.

(From a Report made to the Steam Users Association.)

"Under average conditions one man can run an engine and fire up to ten tons per week.

"For thirty tons it requires an engineer, one day and one night man. This is for about a 200 H.P. plant.

"For a 500 H.P. plant it would require an engineer, two day men and one night man." (This information was compiled from reports of four hundred members.)

"From investigation of six hundred (600) small plants the average cost of handling was 48c per ton, with a maximum of 71c, and a minimum of 26c per ton."

"Where coal was moved by wheelbarrow the cost was 1.6c per ton for the first five yards, and 1c per ton for each additional yard."

Mechanical stokers are almost universally used in power stations on account of the increased efficiency over hand-fired furnaces and the reduced cost of operation.

Equally as good results have been obtained with hand-fired furnaces by careful and intelligent firemen, but the trouble is that such firemen are not plentiful, and it is extremely difficult to secure men who will produce good results all the time. For this

reason the fuel economy will be better where the firemen are assisted by some form of mechanical stoker.

When the coal is deposited in the boiler room so that it requires but one shovelling to the furnace, one man can care for the boiler, coal and ashes of a 400 H.P. plant. If the coal requires two handlings a fireman and helper are required for each battery of 500 H.P. Where automatic stokers are used and coal is fed to the hoppers by gravity, one man can care for 2000 H.P. of boilers.

The cost of mechanical handling varies according to conditions and the size of the plant. The smaller the plant the greater the cost per H.P., both for installation and operation, while for the the larger plants the labor cost for the mechanical transferring of coal from cars to stokers is as low as 2c per ton.

In reply to the query of "The amount of saving accomplished by the installation of machinery," one manufacturer states "As near as we can approximate, our saving (including repairs, depreciation and interest on investment), is about $3,500.00 per year."

The cost of this plant was $16,950.00. This shows a return of 23½% on the investment.

Another case: Where a 4000 H.P. plant with coal dumped from trestle alongside of building, required eight men to stoke and eight helpers on each turn. The labor cost amounted to $18,200.00 per year; when the plant was equipped with mechanical stokers and coal handling machinery, including an overhead bin at a cost of $26,000.00, the labor cost was reduced about $13,400.00 per year. This, with the interest, depreciation, repairs, etc., deducted, showed a return on the investment of about 37%.

Other cases might be cited where the returns showed as high as 75 to 80 per cent. on the investment, but such cases are rare. However, 20 to 40 per cent. returns on the investment are generally the case.

As conditions for every plant differ, no fixed solution can be offered, but each case must be treated as a separate problem.

The type of machinery and method of handling depend upon—

The size of plant.
The kind and size of coal.
The rate or capacity at which coal is to be handled.
The location of the delivery point.
Whether reserve storage, and how much.

Where the coal is small, as well as the capacity, the simplest method consists of—

Track hopper.
Elevator.
Conveyor.

If the coal is lumpy, and capacity *not* an important factor, a grating (with about 6″ sq. openings), is placed between the dump and the elevator. The large lumps are broken on this grating.

Where bituminous coal is handled and stored in an overhead bunker, the coal should be crushed before elevating.

Assuming that the size of plant justifies the installation of mechanical handling, then—

The design of the machinery should embody

Simplicity.
High efficiency.
Durability of construction.
Immunity from breakdown.
Low first cost.
Low cost of operation, and
Low cost of maintenance.

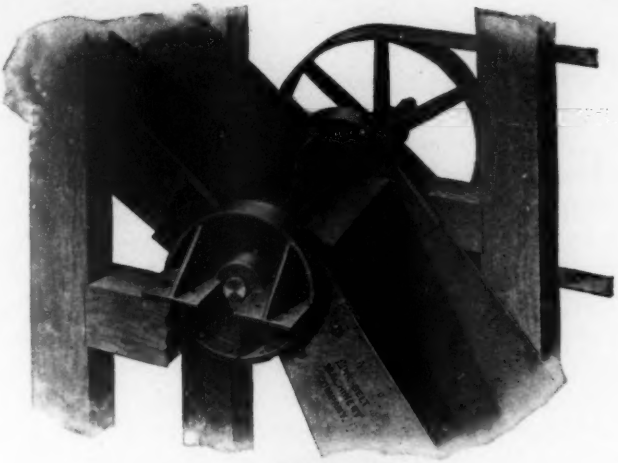
The receiving hopper should be constructed so that the coal will run freely down the corners, and the opening of such a size that the coal will not jam. If the coal is of small size, with no large lumps, it can be controlled by the use of a slide gate, but if large lumps are to be handled an opening of sufficient size would permit the coal to flow faster than the machinery could take it away, and could not be controlled by a gate without the constant supervision of an attendant.

Several automatic feeding devices have been designed to eliminate this annoyance and regulate the flow, among which are the—

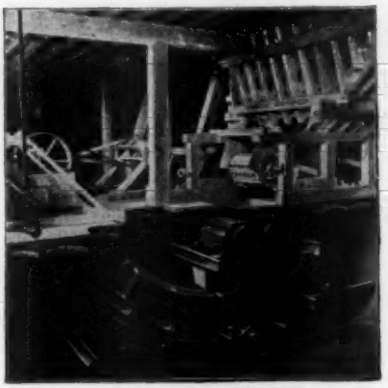
Roll Feeder;
Apron Feeder, and
Reciprocating Feeder.

The *roll feeder* was first used for handling ore, and was found very efficient. It consists of a drum with angles fastened to the outer surface. This requires considerable head room, and a modification consists of a cast-iron drum, with pockets or blades radiating from the sleeve, (see cut 1813).

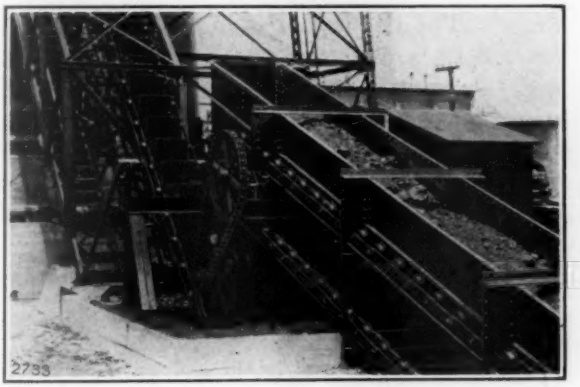
The *apron feeder* consists of two chains with overlapping steel slats forming a continuous belt. This form is best where a



(1813) Roll feeder.



(1472) Apron feeder. 25th Ward Gas Works, U. G. I. Co., Philadelphia.

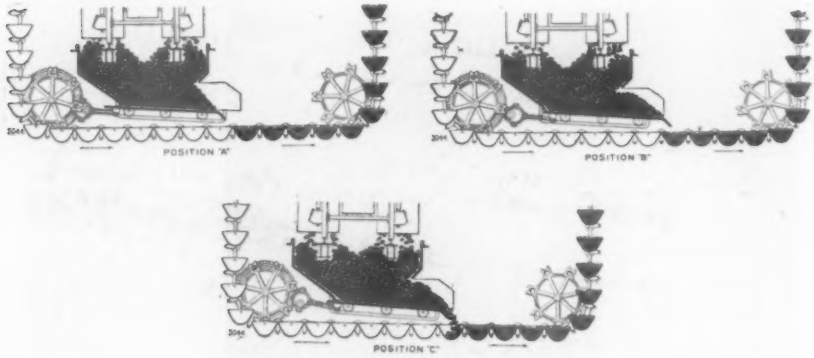


(2733) Apron feeder as conveyor at Semet Solvay Co., Geneva, N. Y.

steady, continuous feed is required (see cut 1472), or where the hopper is at a distance from the elevator, the feeder acting as a conveyor (see cut 2733).

The *reciprocating feeder* is much simpler and cleaner, there being no spill from damp, sticky coal. It is used where an intermittent feed is required. It can be timed to operate with spaced buckets, discharging the proper amount in each bucket as it passes the feeding point (see cuts 3044, a. b. c.)

It consists of a flat plate mounted on rollers and operated by an eccentric connected with the elevating machinery. The amount delivered is regulated by the throw of the plate. The mechanism is so made that this throw can be quickly adjusted, thus increasing or decreasing the amount delivered by each reciprocation.



(3044 a. b. c.) Reciprocating feeder.

The three different views show the method of operation. The movement forward of the plate (Position B) carries the coal with it, while the supply in the hopper crowds down to fill the space made vacant. With the return movement of the plate (Position C) the material is forced over the end into the bucket (or crusher, if crushing is necessary). When the plate is in its innermost position the outer end should be slightly beyond the line of repose of the coal.

Provision should be made for the installation of a crusher. If fine or crushed coal is received it can be by-passed around the crusher.

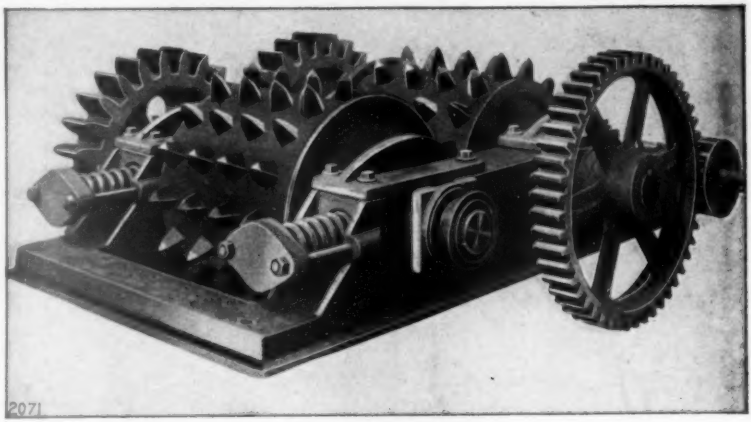
As it is not always possible to obtain small coal the crusher will be found necessary, and should be placed as near the receiving

point as possible, so as to avoid the use of large machinery to handle the large lumps of coal.

The crusher (see cut 2071) should be of a very rugged design, and provided with spring release, so that should obstructions, such as wood or iron, get into the rolls the latter would spread sufficiently to allow the foreign materials to pass between them without danger of smashing the frame.

CRUSHERS.

Crusher Size.	Tons Cap.	Max. Lumps.	Crushed to.	H.P. Reqd.	Speed Rolls.	Speed Ctr.
20″ x 24″	30	12″	2½″	5 : 7½	40	150
28″ x 24″	50	R. of M.	4 ″	7½ : 10	56	200
28″ x 36″	85	″	4 ″	10 : 15	72	200



(2071) Crusher with spring release.

From this stage on the machinery may differ, according to the requirements, and may be divided into two classes:—

A. An elevator with separate conveyor, or

B. A combined elevator-conveyor.

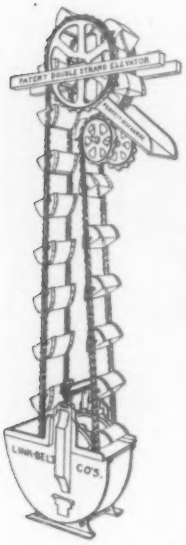
A. Elevators are of four types, namely:—

1. Centrifugal Discharge.
2. Perfect Discharge.
3. Continuous Bucket.
4. Skip Hoist.

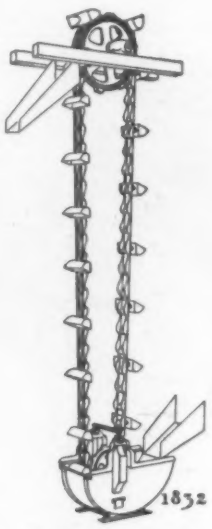
1. Centrifugal Discharge Elevators (see cut 1832), consist of a single strand of chain or belt with buckets attached at intervals,

and run at high speeds of from thirty to forty revolutions of the head shaft, or from 200 to 400 feet bucket speed. The coal is thrown out and has considerable breakage, with a great deal of dust.

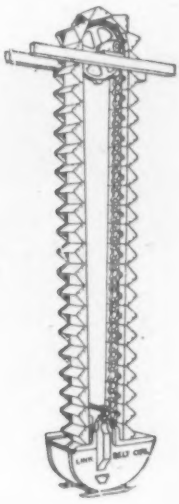
2. Perfect Discharge Elevators (see cut 1831), consist of two strands of chain with buckets at intervals between. A pair of idler wheels set under the head wheels cause the buckets to be completely inverted and make a clean delivery into the chute at elevator head. The speed is much slower than the Centrifugal Elevator.



(1831) Perfect discharge elevator.



Centrifugal discharge elevator.



(1829) Continuous bucket elevator.

3. Continuous Bucket Elevators (see cut 1829), are of either single or double strand chains, with buckets attached continuously. Each bucket after passing over the head wheel acts as a chute for the following bucket. The speeds are slow—from 90 to 200 feet per minute.

4. A Skip Hoist consists of a large bucket or skip connected to a hoisting drum by means of wire ropes. The skip runs between guides or tracks so arranged that at the top the bucket is inverted and the load dumped. This machine requires an attendant at the

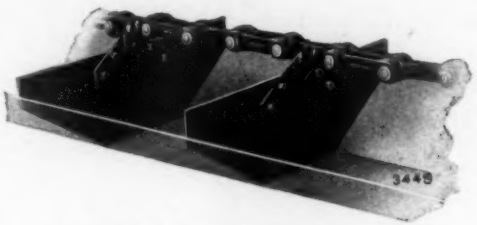
loading point. When an electric hoist is used an automatic reverse attachment is employed, so that by throwing in a switch the skip will rise, discharge its contents, and then automatically return to the loading point.

Conveyors may be Screw, Scraper, or Belt.

Screw Conveyors consist of a helical steel flight mounted on a shaft (solid or pipe), and run in a ⋃ shaped trough. These come in sections from eight to twelve feet long and from nine to eighteen inches in diameter. The capacity ranges from ten to thirty tons per hour with speeds of about sixty revolutions per minute.

It is not advisable to use this form of conveyor for coal, as it will only handle the smaller sizes, and is easily damaged by any foreign substance of unusual size or shape.

Flight Conveyors consist of a trough of any desired cross sec-



(3449) Plain flight conveyor—maximum chain.

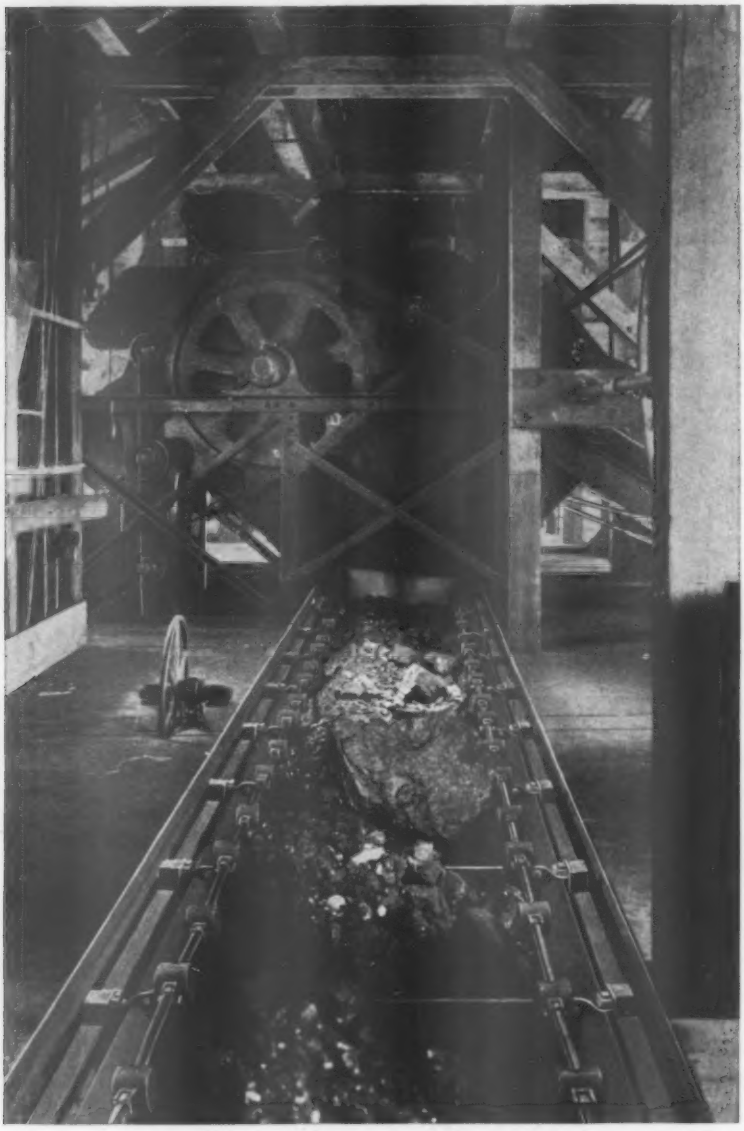
tion, either single or double strand of chain carrying scrapers or flights of approximately the same shape as the trough. The flights push the coal ahead of them to any desired point, where it is discharged through openings in the bottom of the trough.

Flight Conveyors are of three types:—

Plain Flight.
Suspended Flight.
Roller Flight.

The *Plain Flights* (see cut 3449), are attached to the chain, and drag along the bottom of the trough. Conveyors of this type are of low first cost, and useful when noise is not objectionable, but require more power than the other two types.

The *Suspended Flights* (see cut 1555), are attached to cross bars having wearing shoes at the ends. These shoes slide on angle iron tracks on each side of the conveyor trough. The flights do



(1555) Suspended flight conveyor at Erie Railroad Co., Jersey City, N. J.

not bear on or touch the trough at any point. This type is of higher first cost than the scraper, but takes about one-fifth less power, and is used where quietness of operation is a consideration.

The *Roller Flight* (see cut 1704), is similar in construction to the suspended flight, except that rollers replace the wearing shoes. It is of highest first cost, but has the advantages of low power consumption (about two-thirds that of scraper), and noiseless operation.

(1704) Roller Flight Conveyor—Monobar Chain. Allegheny City Water Works, Allegheny, Pa.

CAPACITY OF FLIGHT CONVEYORS IN TONS PER HOUR AT SPEED OF 100′ PER MINUTE.

Material 50 lbs. Per Cubic Foot. *Flights Spaced 24″ C.*

SINGLE STRAND.					DOUBLE STRAND.				
Size of Flight	Inclination of Conveyor 0°	10°	20°	30°	Size of Flight	Inclination of Conveyor 0°	15°	30°	45°
4″ x 10″	22	18	14	10	8″ x 16″	82	62	41	27
4″ x 12″	28	24	18	13	10″ x 20″	129	97	63	43
5″ x 12″	34	28	22	16	10″ x 24″	154	116	77	52
5″ x 15″	46	40	31	22	12″ x 30″	222	167	111	75
6″ x 18″	60	49	40	31	12″ x 36″	270	203	135	90
8″ x 18″	90	72	57	48	12″ x 42″	315	226	157	105
8″ x 20″	105	84	66	56	12″ x 48″	360	272	180	120

Belt Conveyors (see cut 2327), consist of head and foot drums or pulleys connected by an endless flexible apron. This apron is, usually, of rubber or cotton belt. The intermediate supports for

the belt consist of idler pulleys spaced from 4 to 5 feet on the carrying side, and about 10 feet on the return.

The carrying idlers are so shaped that the belt is troughed for its entire length. When properly designed, and under certain conditions, belt conveyors prove highly satisfactory, and are better in some cases than any other type of conveyors. To give the best and most lasting results the belt should not be excessively troughed, and the idlers thoroughly lubricated. The speeds vary from 200 to 800 feet per minute, and have capacities as follows:

(2327) Belt conveyor at Maryland Steel Co., Sparrows Point, Md.

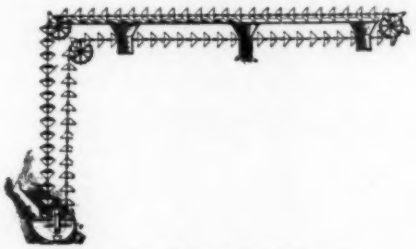
CAPACITIES BELT CONVEYORS IN TONS AT 50 LBS. CU. FT.

Width of Belt.	*Velocity of Belt Feet per min.* 200	300	400	500	600
14″	24.5	36.7	49.	61.3	73.
16″	32.	48.	64.	80.	96.
20″	50.	75.	100.	125.	150.
24″	72.	108.	144.	180.	216.
30″	112.	168.7	225.	281.	337.
36″	162.	243.	324.	405.	486.

NOTE.—At 400′ per min. the capacity in tons per hour (for coal at 50 lbs. per cu. ft.), is equal to one-half the width of belt squared. $\left(\frac{W}{2}\right)^2 =$ tons per hour.

The limiting angle for belt conveyors is about 20°, as above this the coal will slide or roll back and spill, even at 20° the feed must be steady, so that the material forms one continuous pile along the center of the belt.

Belt conveyors have high carrying capacity and low power consumption, but are relatively high in first cost and repairs. Where discharge at intermediate points are required a *traveling tripper* or dumper is used. This can be hand propelled or power driven, the power being supplied by the belt.

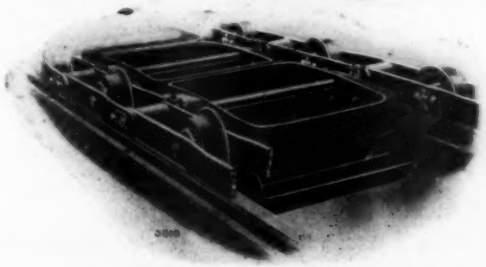


(3195) Gravity discharge elevator conveyor.

H.P. OF 100′ CONVEYOR AT 100′ PER MIN. FOR COAL.

Inclination.	Size of Belt.					
	14″	16″	20″	24″	30″	36″
0°	.25	.31	.42	.57	.88	1.20
5°	.35	.45	.67	.97	1.57	2.31
10°	.45	.59	.92	1.37	2.26	3.42
15°	.55	.73	1.17	1.77	2.95	4.53
20°	.65	.87	1.42	2.17	3.64	5.64

NOTE: Add 20% to H.P. if Tripper is used.



(3010) Pivoted buckets with retrievers.

B. Combined Elevator Conveyors are of the following types:

1. Gravity Discharge.
2. Rigid Bucket Carriers.
3. Pivoted Bucket Carriers.

1. The *Gravity Discharge* type (see cut 3195), consists of

V-Buckets rigidly attached at intervals between two strands of chain (preferably roller). After passing around the turn wheel from the vertical to the horizontal, the buckets act as conveyor flights and convey the coal similar to a scraper conveyor. This is the cheapest form of combined elevator-conveyor, and is economical of power.

H.P. OF V-BUCKET ELEVATOR-CONVEYOR AT 100′ P.M. AND CAPACITIES.

Size of Bucket L. & W.	12″x12″		16″x15″		20″x15″		24″x20″		36″x20″	
Spacing of Bucket	18″	36″	18″	36″	18″	36″	18″	36″	18″	36″
HP for ea. 10′ Vert. Lift	.46	.23	.9	.45	1.06	.57	2.4	1.2	3.8	1.9
HP " " 100′ Hor. Empty	1.2	.9	1.5	1.1	1.6	1.2	2.2	1.5	2.4	1.6
HP " " " " Anth.	2 5	1.5	4.0	2.3	4.7	2.8	8.8	4.8	12.4	6.6
HP " " " " Bit.	3.2	1.9	5.3	3.0	6.5	3.6	12.3	6.6	18.	9.4
Capacities level full tons per hour	31	15.5	61.4	30.7	78	39		82.5		124

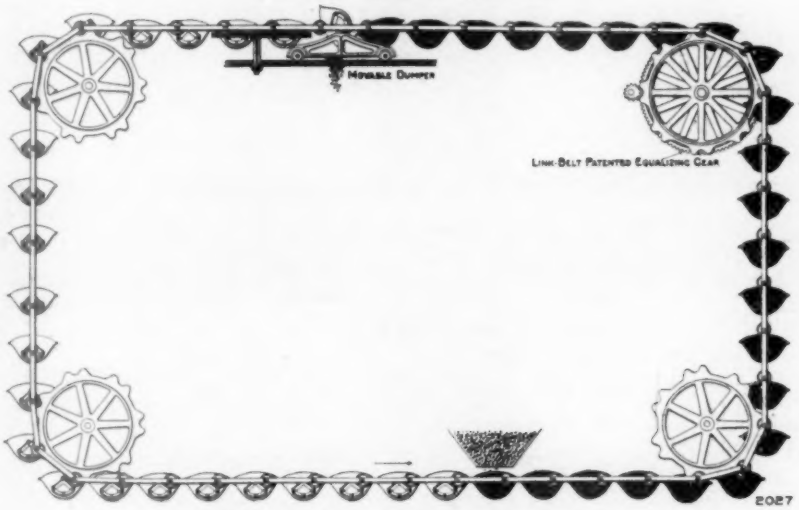
2. Rigid Bucket carriers are made of specially shaped buckets carried between two strands of long-pitched steel roller chain. The buckets are shaped so as to carry coal around three sides of a rectangle. To discharge the load it is necessary to temporarily invert the bucket by passing through a *dumping carriage.*

3. Pivoted Bucket carriers consist of malleable or wrought steel buckets suspended from shafts running between two strands of long-pitch chain. The buckets are arranged so that their adjacent lips are close together or overlapping. Carriers in which buckets do not overlap should be fitted with auxiliary buckets or retrievers arranged in such a manner as to catch the spill (see cut 3010), which falls between the lips at the loading point, and designed so as to return the coal thus caught to the pivoted buckets as the conveyor changes from the horizontal to the vertical run. The overlapping bucket (see cut 2027), is pivoted from an extension arm of the inside chain links. On account of this when the buckets pass around the corner turns they describe a larger curve than the chain proper, and separate to such an extent that there is no interference between the overlapping lips, and are at all times, except when discharging, in a natural horizontal position. Pivoted buckets will carry around four sides of a rectangle, and are dumped on the horizontal run over a cam dumper. The turns under stress should always be over wheels, and not around curves.

CAPACITIES AT 40′ PER MINUTE.

Size.	Max. cap. Bucket lbs.	Tons per hr. at .8 max.
24″ x 18″	84	40
24″ x 24″	112	54
24″ x 30″	140	68
24″ x 36″	163	82
24″ x 42″	196	96
24″ x 48″	224	110

Maximum Speed 60′ per min.



(2027) Pivoted buckets—overlapping type.

H.P. OF PIVOTED CARRIERS.

Place of Installation.	PATH. Hor.	Ver.	Coal Handled.	Speed.	Cap. Tons.	H.P. Empty.	H.P. Full.
Rockingham L. & P. Co., Portsmouth, N. H.	150′	52′	Bit. Slack.	38′	30	3.3	5
Washington Navy Yard	103′	33′	Crushed Bit.	46′	30	3.0	5 *
Penna. Railroad, Rerovo	64′	49′	" "	45′	33	2.7	4.6
Penna. Railroad, Altoona			" "	46′	33	2.4	5.3
Wanamaker Power House	75′	114′	Buckwheat	42′	40	6.2	15.4*
Brooklyn H'ts R. R. Co	380′	110′	"	54′	92.3	9.9	21 *

*Drives Reciprocating Feeder.

OVERHEAD STORAGE.

The storage of coal overhead enters very largely and vitally into the cost of handling:

1. Convenience.
2. It avoids the expensive wheeling in case of a breakdown of the machinery.
3. Avoids running the machinery continuously.
4. Coal under cover will not freeze in winter, and clog the supply pipes to the boilers.
5. Sometimes cheaper to store overhead than to use valuable ground space.
6. As distinguished from vault or outside storage it is cheaper to build steel bins than masonry pits.

The amount of this overhead storage depends a great deal upon local conditions, and whether coupled up with an outside storage.

For power, lighting and pumping stations where the results of an enforced shut-down, through lack of fuel, would be disastrous, the capacity of this storage should be of sufficient amount to supply the wants during the interruption of the supply. For ordinary conditions this should be of sufficient amount to take care of a five- to ten-days' run when the plant is working at full capacity.

The smaller overhead bins are, usually, constructed of steel.

The cheapest type of steel bin is the "Berquist Suspended" Bin (see cut 2344), and is made in sizes from one ton per foot capacity up.

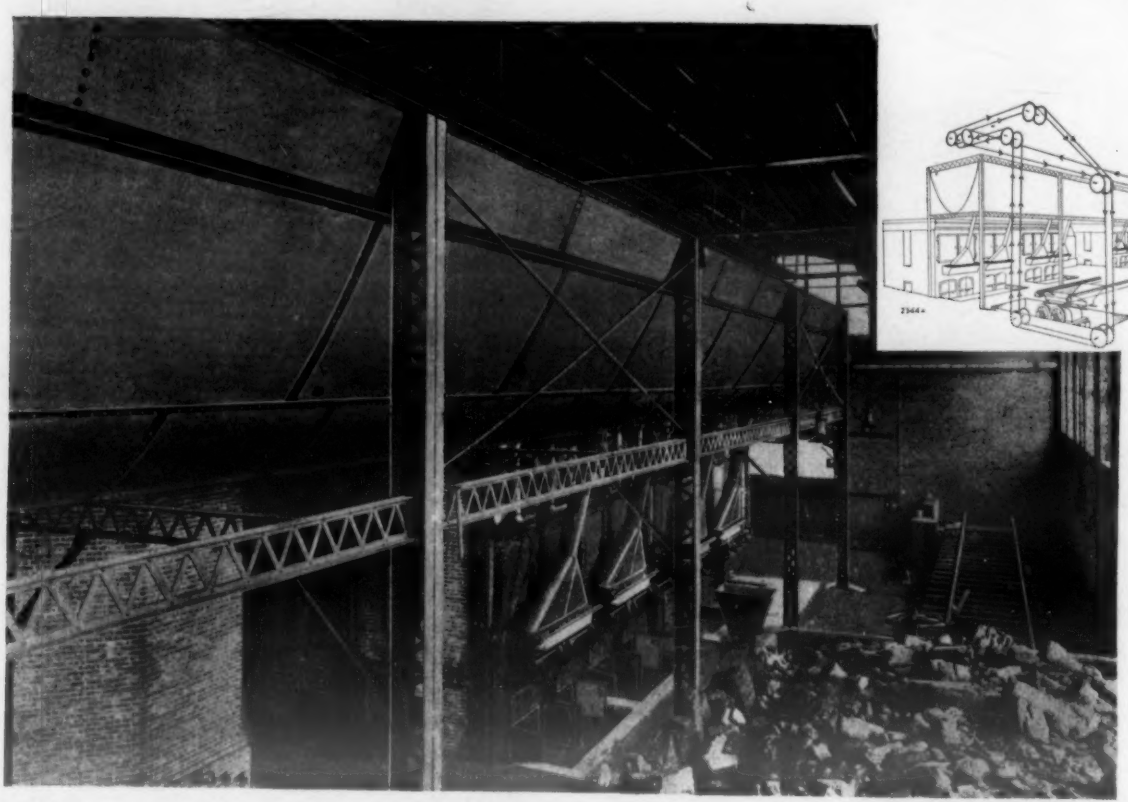
COMPARISON OF WEIGHTS OF DIFFERENT SHAPED BINS.

Place of Installation.	Total Cap. Tons.	Cap. per ft. Tons.	Total Wght. Steel.	Weight without Spts.	Proportional. With Spts. Coal.	Steel.	Without Spts. Coal.	Steel.
Crucible Steel*...	350	3	113,300	87,250	6.15	1	8	1
Morrison & Cass*.	500	3	111,600	81,725	8.95	1	12.2	1
S. J. E.&T. Co....	76	1½	35,960	23,390	4.23	1	6.5	1
Raritan Cop. Co..	118	1¾	40,350	40,350			5.85	1

For the larger sizes, say above six tons per foot capacity, the usual construction is a combination of a steel skeleton with reinforced concrete floor and sides.

Spouts from overhead storage to boilers should be of ample size to permit the passage of coal without clogging, and for

*Berquist Type.

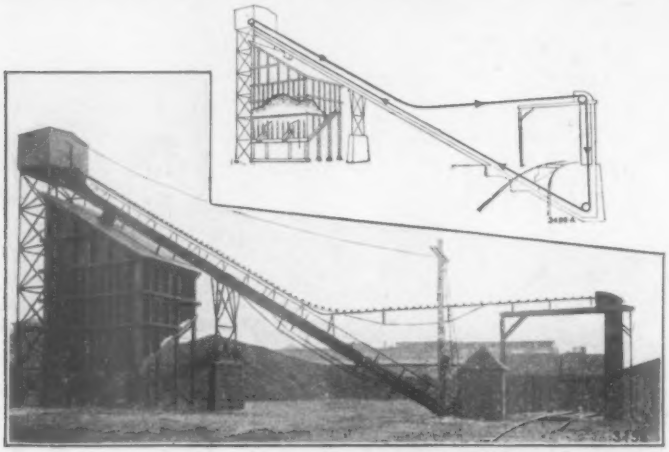


(2444) Boiler house equipment, Crucible Steel Co., Jersey City, N. J. Consists of 350-ton Perquist suspension bunker with elevator and conveyor for delivering coal to same and crusher for crushing coal, as it is automatically delivered from track-hopper by means of a Link-Belt reciprocating feeder. Machinery electrically driven. Capacity 40 tons per hour. Designed and constructed by The Link-Belt Co., Philadelphia, New York and Pittsburg.

crushed bituminous coal should not be less than twelve (12) inches in diameter.

Other forms of storage are the vault storage, where the railroad cars are run onto a trestle and dumped, and the independent bin along the front of the boiler house (see cut 1533). Both of

(2634) Outside storage—bituminous coal. Thomas Potter Sons & Co., Philadelphia, Pa.

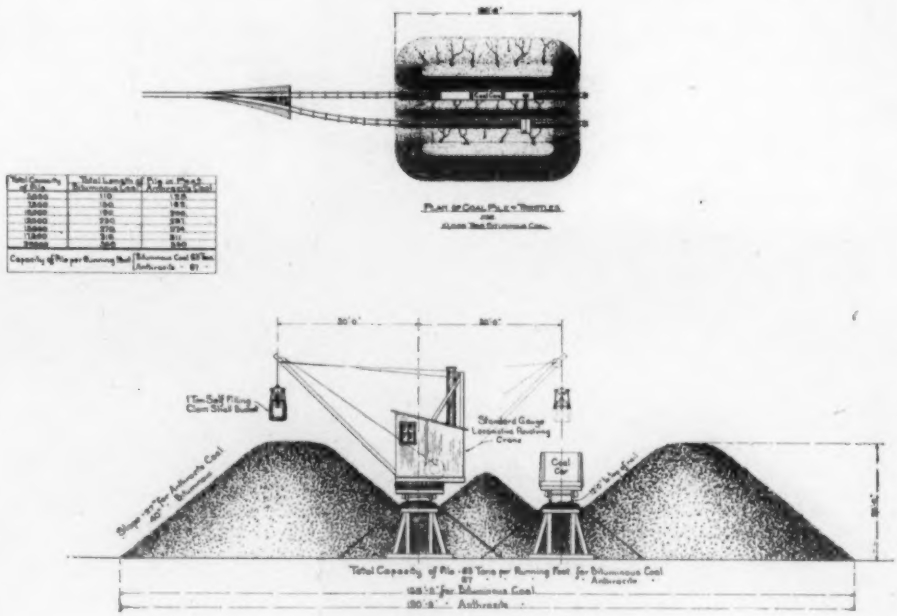


(3496) Outside storage—anthracite coal. Weideman Silk Dyeing Co., Paterson, N. J.

these types are common where the boilers are in a single line. The coal is shoveled to the boiler, or chuted to machinery which takes it direct to the stokers or small overhead bin.

For small plants a very efficient rig is the *Traveling Elevator*, but the cost of installation, including storage pit, foundations

(2023) Trestle storage with locomotive crane.



(2023) Trestle storage with locomotive crane.

(3533) Locomotive crane with central pit. Michigan Alkali Co., Wyandotte, Mich

and structural supports for track, will run much higher than an overhead bunker of the same capacity.

Ground or *Outside Storage* (see cuts 2634 and 3496).

This may be divided into two classes,—*Bituminous* and *Anthracite.*

The maximum depth at which soft coal is stored should not be more than twenty-five feet, and sometimes as low as fifteen feet, owing to its tendency to spontaneous combustion.

Trestle Storage, say twenty feet high, will stock out twenty tons of Bituminous and twenty-five tons of Anthracite coal per running foot of trestle. For a five thousand ton pile it requires about two hundred and fifty feet of trestle for Bituminous, and about two hundred feet for Anthracite. With an approach on a grade of five per cent. this would make the total length of trestle over six hundred and fifty feet. With the price per thousand feet b.m., including bolts at $35.00, the cost of a trestle twenty feet high would be $7.36 per foot, and the total cost would be about $4300.00, excluding foundations. Adding to this the cost of trackmaking would bring the figure up to about $5000.00.

Trestle Storage in connection with a locomotive crane (see cut 2023), reduces the amount and height of trestle, and 5200 tons can be stored in an area of 190′ x 125′ for Anthracite and 155′ x 110′ for Bituminous.

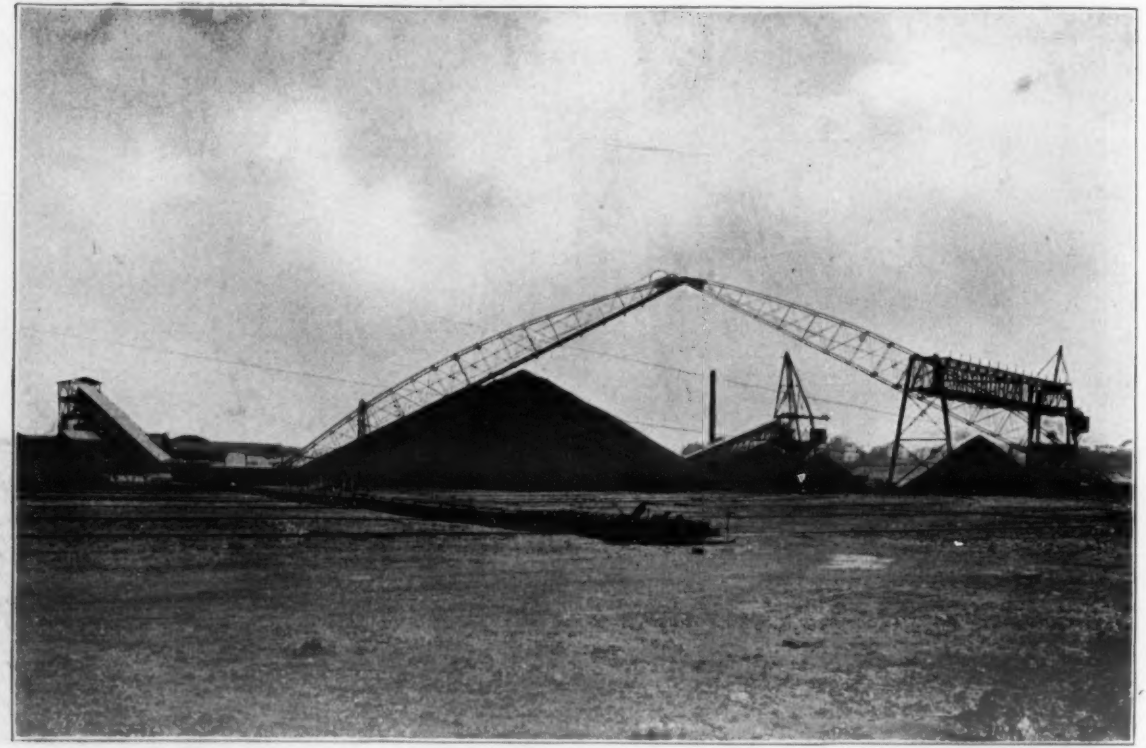
With a 35′ radius crane one man can handle 450 tons a day. Figuring for crane repairs, depreciation, interest, wages and power, the cost per ton would be from 1½c up to 2c. To this must be added the cost of trestle.

Another form of crane storage consists of a central dumping pit, with a circular track radiating from the pit.

With cranes of radii of 35′ to 80′ from 6000 to 40,000 tons can be stored in this way (see cut 3533). This is the cheapest storage system for large bodies of bituminous coal, and combines low cost of handling with low investment cost.

Another type is the *Bridge Tramway* (see cut 2408). This shows a 280′ span bridge equipped with a two-ton self-filling bucket. The bridge swings through an arc of 170° and commands a storage of 50,000 tons. If the circle was completed the storage would be over 100,000 tons. This type is also made with parallel traverse. Cut 2576 shows a combination of bituminous

(2408) Bridge tramway. Maryland Steel Co., Sparrows Point, Md.

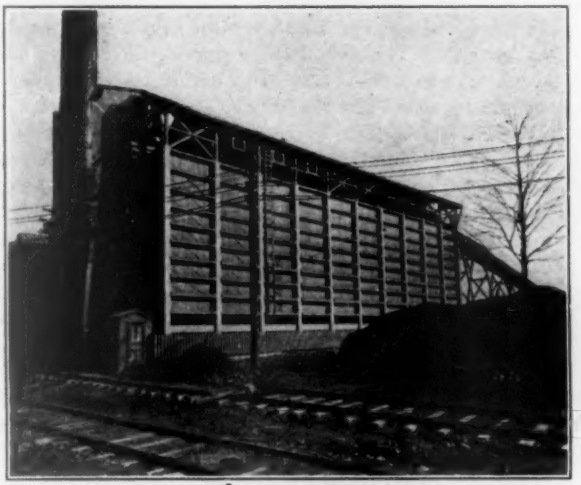


(2576) Dodge coal storage plant. N. Y. Edison Co., Shady Side, N. J. Bituminous and anthracite.

(3017) Dodge coal storage plant. Philadelphia and Reading Coal and Iron Co., Abrams, Pa.

and anthracite storage at the New York Edison Company, Shadyside, N. J., opposite New York City. The accessibility of this base of supply enables the company to meet the fueling demands of its various stations in New York and assures the continuity of their operation. Anthracite is delivered at the storage plant by either rail or water. Bituminous by water only.

The *Dodge System* was the first and is the most successful application of engineering practice in the storing of Anthracite coal. Its effectiveness is due to simplicity of design, mechanical efficiency, and the economy resulting from its operation. It



(1533) Bin along front of boilers. Penna. Mfg. Light and Power Co., Tacony, Philadelphia, Pa.

consists of a chain conveyor supported by a shear truss, constituting a trimming machine, which piles the coal without breakage, delivering it upon the ground or at the ascending apex of a pile as it is formed, and a pivotal or radial ground-conveyor, called a reloader, mounted on a steel frame, and power actuated in all its movements.

As usually arranged for open-air storage on levelled ground, two trimming machines and one reloading machine located between them constitute one group.

Cut 3017 is a general view of the 480,000-ton Bridgeport Transfer of the Philadelphia & Reading Coal & Iron Company,

at Abrams, Pennsylvania. The immense tonnage of this plant is divided into eight (8) piles, four on each side of a central railway system—each pile having a capacity of 60,000 tons. The stocking out capacity is 14,400 tons per day, and the reloading into cars of 10,000 tons per day of ten (10) hours.

THE JAPANESE INTERNATIONAL EXPOSITION.

Aoyama, one of the highest and most beautiful parts of Tokio, has been chosen as the site for the Grand Exhibition of Japan, to be held from April 1 to October 30, 1912. The exhibition grounds will cover a total area of about 290 acres. A road about 480 feet in width will be built, connecting the Aoyama parade ground and the imperial property, near by. Thus far a number of nations have sent their approval of the exhibition to the Japanese Government. The exhibition is to be held, not for the purpose of commemorating any historical event, but to show to the world the development and progress of Japan. The government has planned to spend $5,000,000 from the national treasury, and it is expected that the various provinces and municipalities will appropriate $5,000,000 more to the exhibition. The city of Tokio will contribute $2,500,000 as its share.—*Iron Age.*

A new coal field is being opened up near the coast of California, between San Francisco and Los Angeles, which is expected to have an important effect on the fuel supply conditions in that State. Unlike most beds in the State, which are lignitic in character, this one is an 18-foot seam of semi-bituminous coal. It is expected that several hundred tons of coal per day will soon be produced by these mines, and about 1½ miles of gangway have been opened up.—*Iron Age.*

A 24,000-h.p. steam turbine, which is probably the most powerful turbine for stationary service yet ordered, is reported to be under construction at the Mannheim Works of Brown, Boveri & Cie., for the Krupp steel works and blast furnace plant at Rheinhausen.—*Iron Age.*

Mechanical and Engineering Section.

(Stated meeting held Thursday, March 26th, 1908.)

Casting Pipes in Permanent Molds.

By Edgar A. Custer.

In the February issue of a magazine devoted to foundry practice, a writer in speaking of the limitations of molding machines made this statement: "A mold that molten iron would not destroy or one in which the evils of unequal heating and cooling would not show on the finished article, was as far removed as the Philosopher's Stone."

The purpose of this paper is to describe method and apparatus using permanent molds, that the hottest iron attainable from the cupola does not destroy, and produces cast-iron pipe in which the supposed evils of unequal heating and cooling not only do not appear, but do not exist.

So-called permanent molds are not new. For many years small iron castings have been successfully made in iron molds, and this without great detriment to either the casting or the mold. These castings, however, were invariably very small and were chilled to extreme hardness. Fortunately it was not necessary to machine them. This limited the use of such molds very materially. Some years ago the Latrobe Steel Co. cast car couplers in iron molds. Within a few months, an article has been published, describing a successful method of making brake shoes in this manner. These shoes weighed about twenty pounds each and with the exception of steel ingots and car couplers were the heaviest castings made in iron molds. So far as can be learned, this is about the extent of the art. It has been the dream of every foundryman whose trade requires a large number of duplicate castings, to make these castings in molds that would not

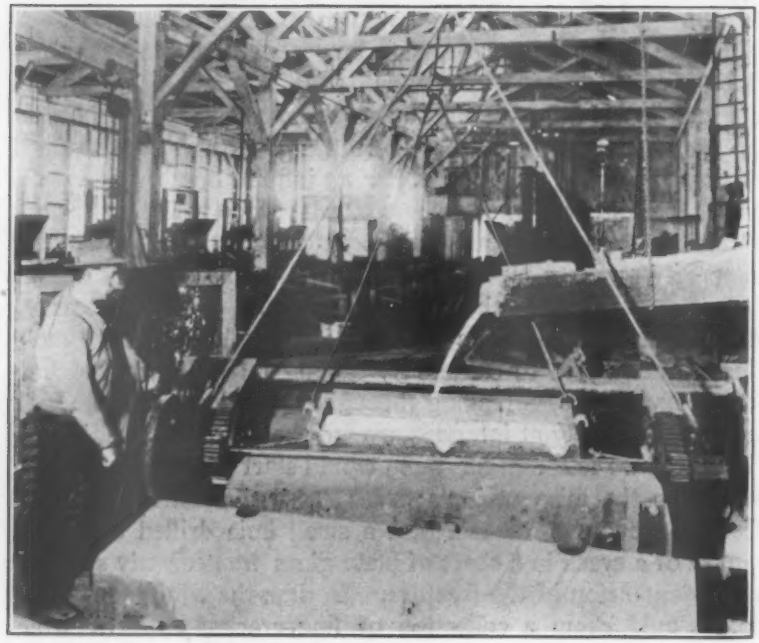
only survive the process, but would also produce castings that would be marketable and be easily machined.

THE METHOD RELATES ONLY TO SOIL, WATER OR GAS PIPE.

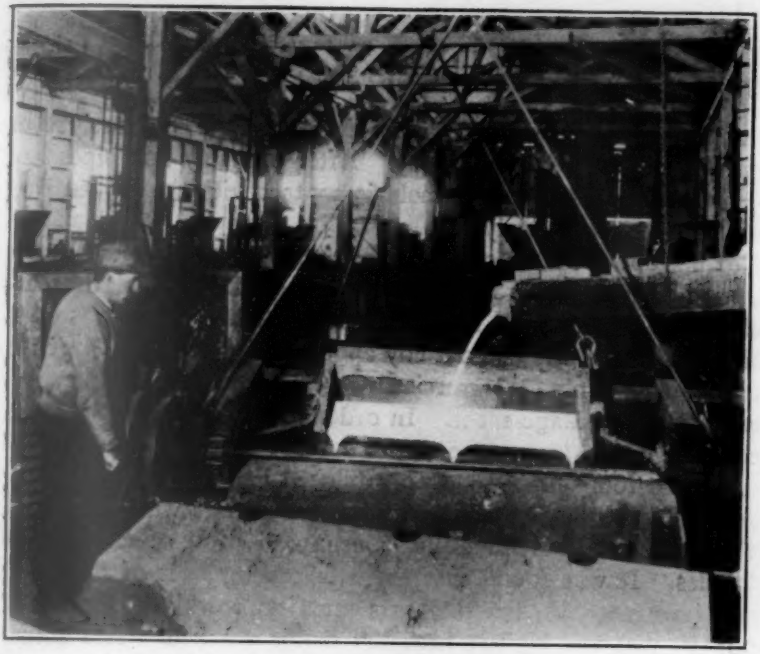
You are probably all familiar with soil pipe making. Iron flasks, a cope and drag, are rammed with sand over a metal pattern; a green sand core is introduced, and the cope and drag are clamped together. The pipe is then poured, with the pipe in a horizontal position, and after cooling, the pipe is removed from the flask and carried to the end of the floor where the cores are removed. Then it is carried to the cleaning room where the sand is rattled off, the gates and fins are removed, and after inspection it is ready for shipment. Altogether the pipe has to be handled ten times. In this process the loss is very great. So much depends upon the condition of the sand; it may be too wet or too dry; the molder may ram carelessly, or may pour his iron negligently, so that the foundry loss often reaches 12% to 15%. In summer weather the output is decreased 25% to 40%, due to the inability of human beings to stand the exacting and exhausting labor. Only one heat a day can be poured in any season. In fact, with very few improvements, and these relating mainly to cores, we are making soil pipe in precisely the same manner and with just as much labor per pipe as was the practice fifty years ago. It is true that the workman of to-day makes more pipe in one day than his grandfather did, but this is due more to the fact that the present-day workman is working by piece and has become infinitely more skilled in saving the seconds of time for each particular operation and avoiding the useless motions in performing them. Any process that would save the use of sand for the mold and would produce pipe that could be easily cut would of necessity be very desirable. If in addition it would obviate cleaning and chipping and could be run continuously night and day, it would very nearly meet the conditions of an ideal business. When experiments to discover and perfect such a process were undertaken, the first mold made was closely modelled from the flasks in use in the sand process. In fact, all the traditions of foundry practice were closely followed. The apparent danger of pouring molten iron into iron molds encasing a damp sand core, was considered to be serious, and the problem of disposing

of the resultant gases was thought would prove to be a great one. Again, the pipes were less than one-fourth inch thick and it was necessary to pour the iron very quickly. So far as was known, no one had successfully poured a complete pipe in an iron mold, and such attempts that had been made had destroyed the mold very quickly. A mold six feet long would be permanently warped in a short time, hence it is not surprising that the experiments were approached with considerable trepidation. The first mold made consisted of a cope and drag, each six feet long, ten inches wide and six inches thick, with gates cut into the drag, as shown in Fig. 1. This mold was cast of very soft iron and the pipe shape bored out. The pouring holes "A" were tapered so that when the cope was removed the iron in them could be easily knocked out. In order to avoid as far as possible all traces of moisture the mold was heated to 500° F., an ordinary green sand core was inserted and four men poured molten iron into the gates. These men wore goggles and were swathed completely in wet cloths. We did not then know what would happen. As it turned out nothing happened—not even a semblance of pipe—the gates were too small. A short session with a hammer and chisel made them larger, and on the second attempt a complete pipe was poured. It was not a remarkable pipe except for its defects. It was streaked with cold shot, the top was filled with flat spots where the gases had been trapped, and it was as hard as flint. After an infinite number of experiments the mold now in use was evolved. A complete description of this mold as it appears on the machine will be given later. After fifty or sixty pipes had been cast in this mold, it became badly cracked around the gates, and as the process of casting was continued these cracks extended into the barrel of the mold. This we attempted to obviate by casting into a new mold very thin strips of mica, extending throughout the length of the mold and placed radially at intervals around the barrel or mold cavity. The cracks we found in this mold would start as before but would stop when the mica was reached. A good illustration of this effect is shown by the fact that a small hole drilled at the extremity of a crack in a sheet of plate glass immediately stops the further extension of the fracture. In time the whole face of the mold would show a collection of fine cracks, most of which

Finished core.



Pouring.



Original pouring device, ladle in lower position.

Passing core to core setters.

could only be seen with a magnifying glass. They rarely ever were more than 1/16 inch deep. After probably 200 pipes had been cast the surface of the mold in contact with the molten iron resembled an extremely hard graphite. It was dull black in color but did not scale or shell off. In order to thoroughly test the mold, the ends were stopped up with sand and the entire barrel, without a core, was filled with molten iron. This was done thirty or forty times without any appreciable deterioration of the outline. The only care exercised was to take the casting out before heavy shrinkage set it. In order to still further test it, the mold was heated to a temperature of about 1100° F. in a furnace, but it was found impossible to produce pipe under these conditions. The molten iron danced in the mold like water on a hot griddle and the resultant pipe was a collection of closely-knit globules. It was found that the safe casting heat of the mold was about 700° F., but that in a practical working 250° F. to 400° F. was the highest heat the molds reached. The actual time in which metal set was carefully noted and the behavior of the cast metal at extremely high temperatures was observed. Irons high and low in silicon, sulphur, carbon or phosphorus were cast a great many times and copious notes were taken in each case. A small chemical laboratory was established for this work. In all over 4600 pipes were cast in 4″ pipe mold, 2700 in a 2″ mold and over 1100 in a 6″ mold. Not one of these molds shows any signs of deterioration over and above the first cracking as described before; in fact, they are in a far better condition than at the start. Each one has been purposely abused and submitted to treatment that never occurs in practice. A straight edge today laid in the barrel shows the surface to be perfectly straight and the 4600 pipe shows the original marks of the boring-out tool.

It was found that an iron running from 2.00 to 2.25 silicon and high in carbon produced the greatest number of perfect pipes, and when cast-iron of this silicon had a comparatively low sulphur content, the result was still better. Further experiments showed that powdered ferro-manganese when added to the molten iron, immediately combined with the sulphur as a manganese sulphide, and rose to the top of the liquid mass as a slag. An excess of manganese, however, produced a hardening effect

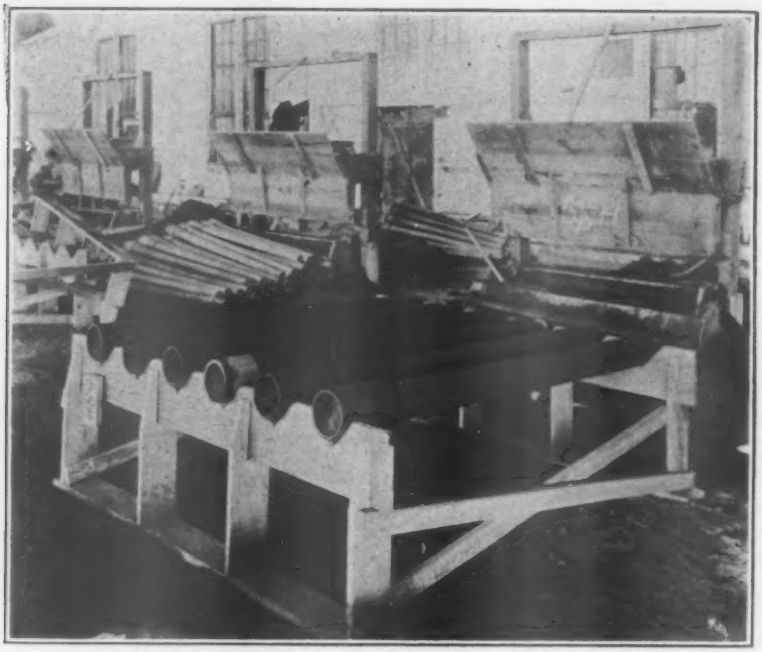
as it formed with the carbon, a carbide which in itself is an extremely hard substance.

These features made it possible to use a high sulphur cast-iron, providing its other contents approximated the figures given above.

It was then noted that pipes that remained in the mold until a dull red heat was reached were very hard, and in most cases were too hard to cut. When they were taken out at a bright yellow heat and allowed to cool normally they were perfect in texture. It was further noticed that when the dull red pipes were piled with the very hot bright yellow pipes, an annealing process was set up that brought the iron in the dull red pipes into a workable condition. This feature of temperature was the subject of a long and patient investigation and the causes leading thereto may be now briefly stated.

Pure iron possesses no fluidity, or the property of low shrinkage, nor does it possess varying degrees of hardness. It is obvious then that the characteristics of cast-iron, which possesses these qualities in a high degree, are due to the presence of impurities, such as carbon, silicon, phosphorus, etc. Carbon is the main element and exists in cast-iron as combined and free carbon. The amount of free carbon, which is the principal softener of cast-iron, depends principally upon the rate of cooling. If molten iron high in carbon be cooled slowly the free carbon separates out in the form of graphitic carbon. If this molten iron be suddenly cooled, the carbon is caught before it has time to separate and is held in an atomic condition by the enormous pressure of the surrounding iron. Therefore, the fracture of a pig of iron is generally an index of the rate at which it is cooled. If the suddenly cooled iron be re-melted and slowly cooled, it will assume all the characteristics of soft iron. The graphitic carbon will become plainly separated and large crystals will be formed. It may be stated that cast-iron in a molten state is a solution of carbon and iron and the mass is homogeneous.

Silicon in itself confers no benefit on cast-iron. It is only its influence on the carbon contents that produces beneficial results. On the other hand an excess of silicon renders cast-iron absolutely unfit for use, making it very hard and brittle. A small quantity through its action on the carbon, reduces shrinkage, in-



Arbors and finished cores, ready for setting.

Original pouring device, ladle in highest position.

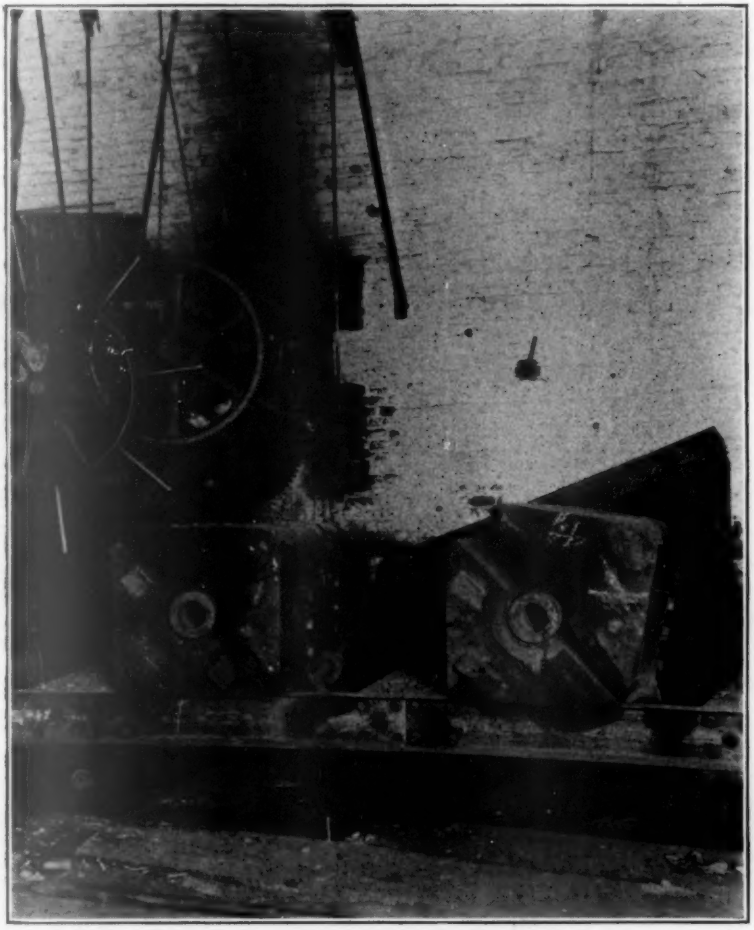
Finished pipe before removal of arbor.

View of machine.

creases strength and increases fluidity. Given then cast-iron comparatively high in carbon with the proper amount of silicon and the ideal conditions are attained. The uses of phosphorus and manganese are too well known to require discussion and play no part in the method except as correctives. Keeping these facts in mind it may be stated that an ordinary foundry iron very nearly fulfils these conditions, with the exception of sulphur. Molten cast-iron is therefore a solution of carbon in iron with the addition of silicon, phosphorus, sulphur and manganese, all forming a homogeneous fluid mass. Now, if this mass be suddenly cooled, it is still homogeneous, the different elements not having time to segregate. If the cooling be continued at the *same rapid rate* until a temperature of about 1600° F. is reached the iron becomes very hard and brittle. But if this sudden cooling is carried out only until the iron is set, and is then removed from the cooling influences, thus allowing the iron to lose its heat normally, the result is a structure whose fracture shows a very fine, close grain. It is tough, since all its particles are thoroughly interlaced, and it is strong because very nearly all the carbon is held in the combined state. In other words, it is homogeneous. Now, let us try to make this vital point plainer.

In a casting, such as a thin pipe, when cast in an ordinary sand mold, it requires about one minute to cool from the temperature of molten iron to the point at which the metal is set. It is in this period that the detrimental effects as shown in cold cast-iron are produced. Phosphorus and sulphur and carbon segregate, and graphitic carbon is formed. Bear in mind that in this period the iron is in a liquid state with all its elements free to move. Once the casting is set all segregation ceases, and the remaining carbon begins its beneficial work. As the iron loses its heat at a normal rate, annealing and carbide carbon are formed, both of which improve the quality of the metal. Now, if we suddenly shoot the molten iron into an iron mold it sets very quickly and the evil period is reduced in time from sixty seconds to two seconds—so short a time, in fact, that all the impurities are held in the position they occupied in the molten mass. The evils of sulphur and phosphorus are reduced to a minimum since they are in practically an atomic condition and are distributed evenly throughout the casting; and since no graphitic carbon is formed all the car-

bon exists as combined carbon, with a corresponding increase in its power for improvement. If the casting is removed from the cooling influence, in this case the iron mold, and allowed to cool normally, the ideal conditions are obtained. Chilling cast-iron to



Immediately after pouring. Mold entering opening device, showing ends of core arbors and mold partially open.

the point of extreme hardness is purely a mechanical process and the point to which the process of sudden cooling can be carried can be determined to an absolute certainty. It is simply a ques-

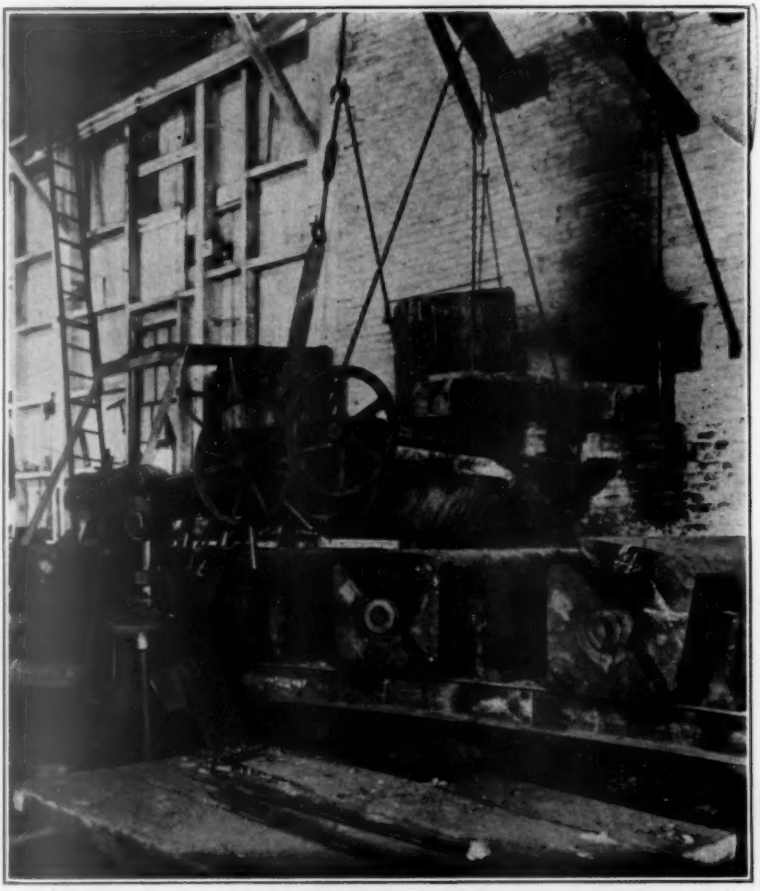
tion of time. The data collected show that a two-inch pipe can be removed two seconds after pouring, and should not remain in the mold more than six seconds. A six-inch pipe can be removed in six seconds after pouring and should not remain more than twelve seconds. This time depends upon the thickness of the pipe walls. Very thin pipe would require not only a shorter time in the mold, but should be cast of iron higher in silicon. The reason for this is that silicon, by its action on the carbon, keeps the iron in a fluid state longer than normal. Every foundryman knows there are irons in which it is impossible to form a chill, and there are other irons in which it is impossible to prevent it. The same limitations apply to making pipe as to the making of other iron products. A suitable iron must be provided if the very best results are to be obtained. This statement applies to any branch of the foundry business and is not set out as a new discovery. What is claimed and demonstrated is, that a poor iron is improved and rendered suitable for the work in hand.

With the data obtained the work of designing a machine that would operate continuously was begun. The experiments had shown that when pipes were cast in a mold every eight minutes, the temperature of the mold never rose above 450° F., even if the operations were continued for hours. If pipes were poured every two minutes the temperature of the mold rose rapidly, and at 900° F. it began to warp. In order to follow the best conditions and avoid the worst, the following apparatus was designed:

The machine consists of an angular table or ring approximately forty feet diameter outside, carrying thirty molds, arranged at equal intervals thereon. The table is constructed of two concentric rings of channel beams, connected with thirty cross pieces or trucks, each of which has two wheels having roller bearing axles. These wheels are arranged to run on concentric circular tracks set in concrete foundations. The tracks are arranged as if on the surface of a cone and by this means is created a tendency of the table to resist any movement other than rotating about its center. Either outer or inner track may be the higher as the effect is the same in either case.

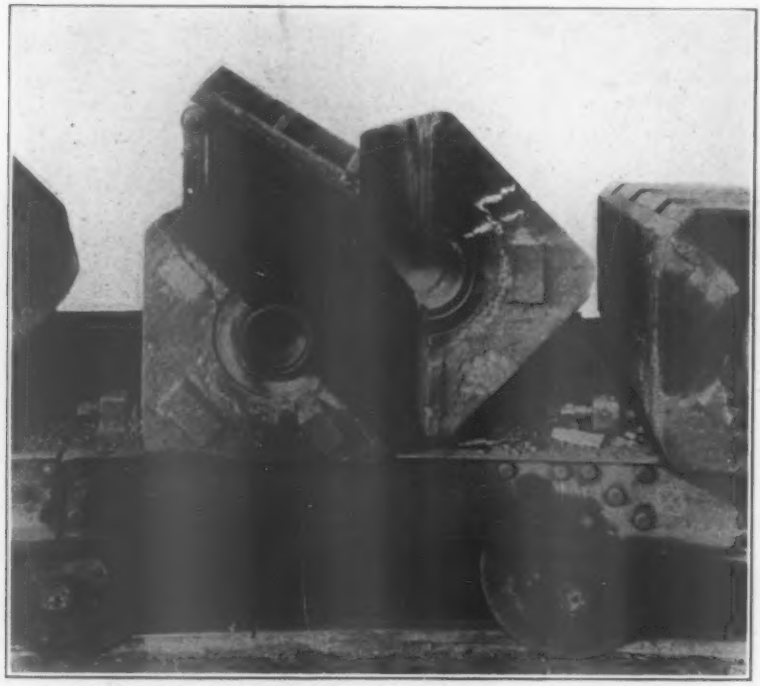
Each truck or cross bar of the table carries a steel pin working loosely in a vertical hole, and of such length as to allow about two inches of pin to project below bottom line of truck, but admitting of being pushed up until flush with bottom of truck.

Under the table or ring, at two diametrically opposite points, are arranged two hydraulic cylinders which slide in ways similar to a planing table, the pistons within the cylinders being held stationary and the cylinder moved back and forth by the operation of a four-way valve controlling the admission of water, alternately to each end of the cylinders. The stroke of the cylinders is of such length as to be slightly more than the spacing of molds carried by the table, and projecting from the top of cylinder is an inclined plane surface designed to lift the pins in the trucks, when



End view original pouring device.

the cylinders move in a direction opposite to the required motion of the table, and to allow a pin on each side to fall, after the inclined surface has passed. This occurs at or near the end of the backward stroke of the cylinders, and when the controlling valve is so moved as to cause the cylinders to move forward, the pins which have been lifted and allowed to fall are brought in contact with the projections on the cylinders and hence the table is car-



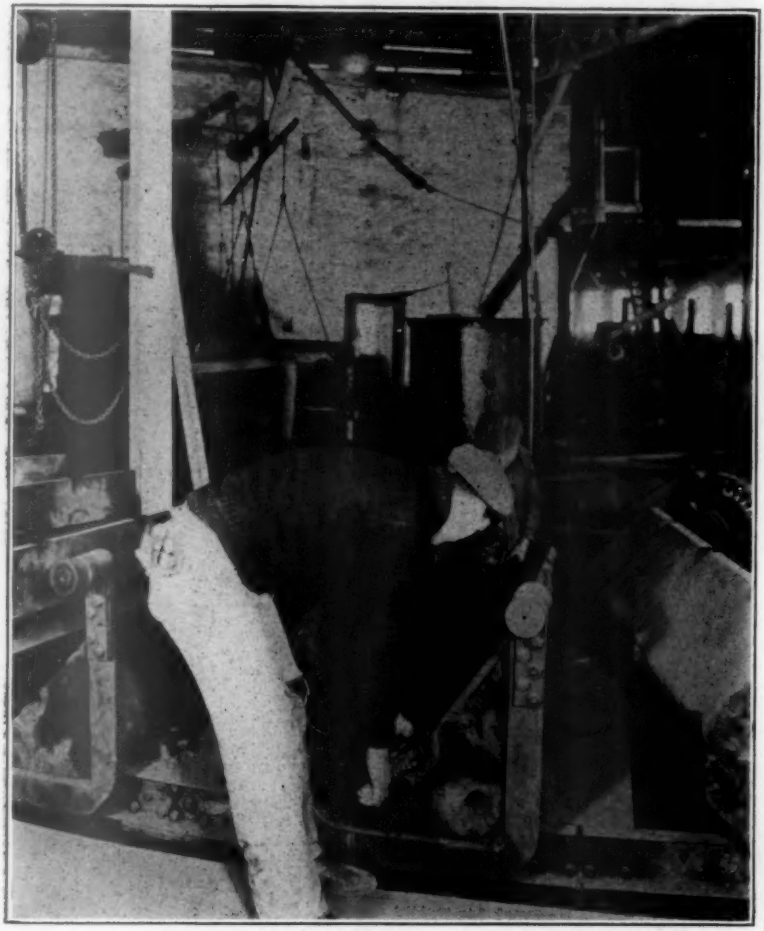
Mold entering closing device. Core in place.

ried forward by the motion of the cylinders, a distance equal to the spacing of the molds, and the cylinders are ready for another return or back stroke to engage the next pins, thus intermittently moving the table ahead one space at each cycle of the cylinders.

The center of the table is left open for the location of hydraulic pumps, operating valve reservoirs, etc., required in imparting motion to the table. This table makes one complete revolution every seven and one-half minutes and consequently produces

thirty (30) pipes in that time, or two hundred and forty pipes an hour.

At certain points about the table are arranged closing and opening devices, which are designed to close the mold, or bring the



Setting core.

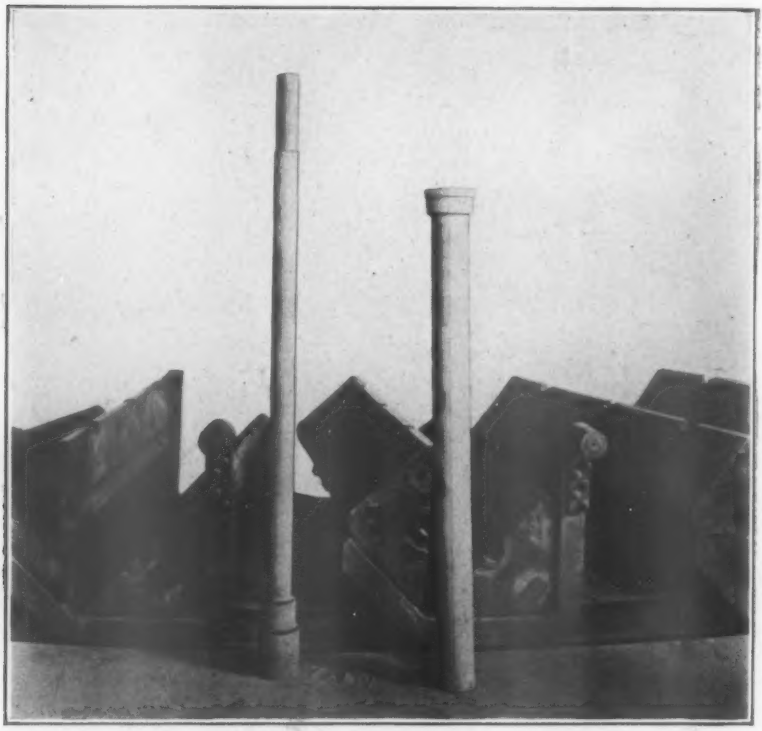
cope side down to its place on the drag side, without shock, after the cores are set in place, and to open the mold or lift the cope after the pipe has been poured.

Between the closing device and the opening device is located

a pouring device adopted to receive the molten metal from the cupola and pour it into the molds.

DESCRIPTION OF MOLD.

Each mold consists of a rectangular block of cast iron, approximately eighteen inches wide and eighteen inches high, by six feet long. parted on a diagonal line across the corners, and pro-



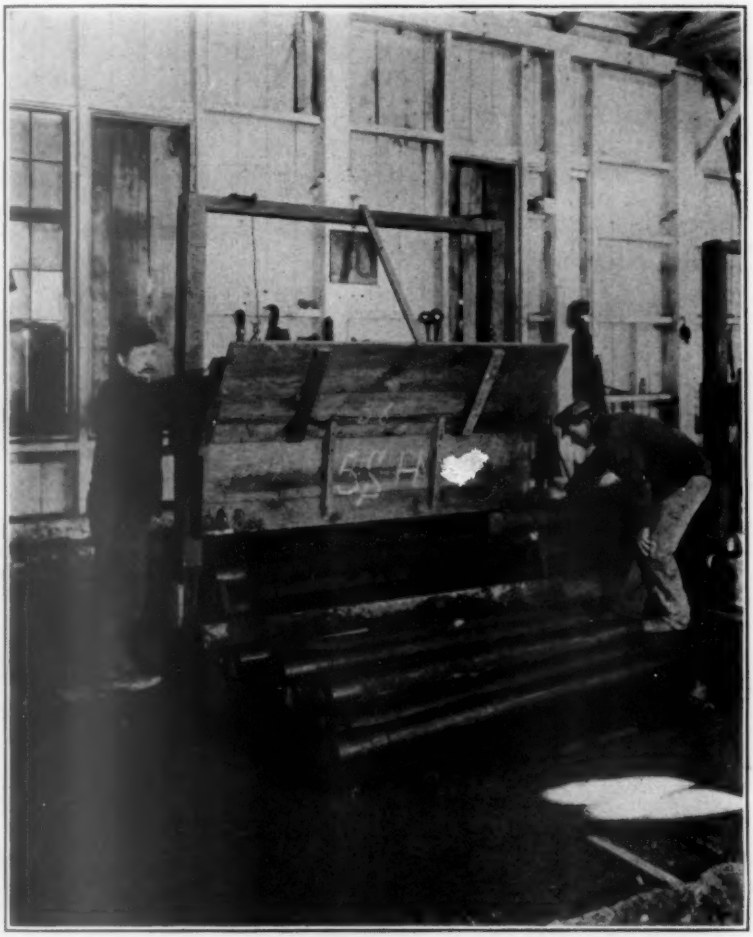
Finished pipe and core arbor. Molds open.

vided with hinges at the lower edge of the parting so as to allow the upper portion or cope to be swung up and back from the lower portion or drag. These molds weigh about 6500 pounds complete.

At the center of the mold is the cavity into which the metal is to be poured to form the pipe. Thus one-half of the pipe is

formed in the upper and one-half in the lower portion of the mold.

Gates are cut in the face portion of the lower part or drag of

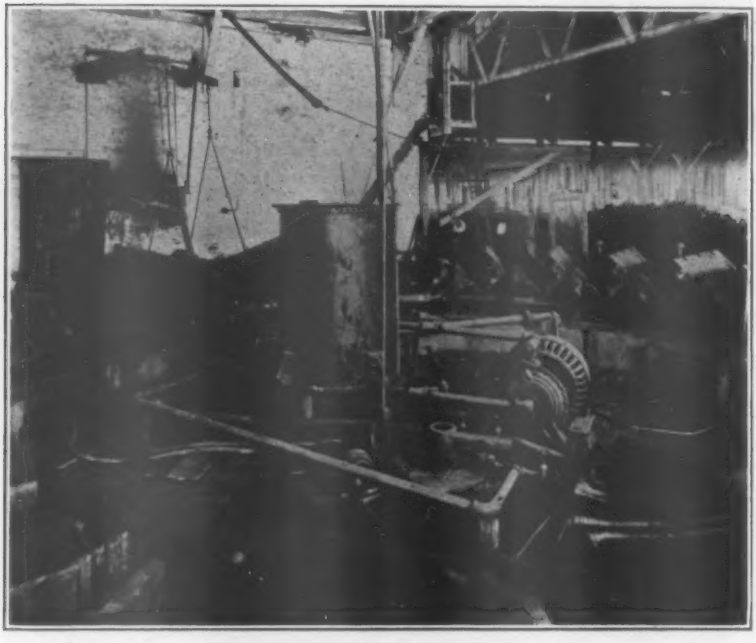


Making cores and core machine.

such size and shape as to receive the molten metal from the ladle and guide it into the mold. Three such gates are used, each dividing into two portions and so entering the cavity of the mold at six points.

(a) These gates are so shaped as to receive the shock of the falling stream of molten metal at a point outside of the mold cavity, and convey it into the mold quickly but gently so that the core is not damaged by a rush of molten metal against it.

(b) At the highest point of the barrel of the mold a small groove is cut, extending throughout the entire length of the barrel. This groove, which is quite small, being only one-eighth of an inch wide and deep, is intended to receive any gases or air

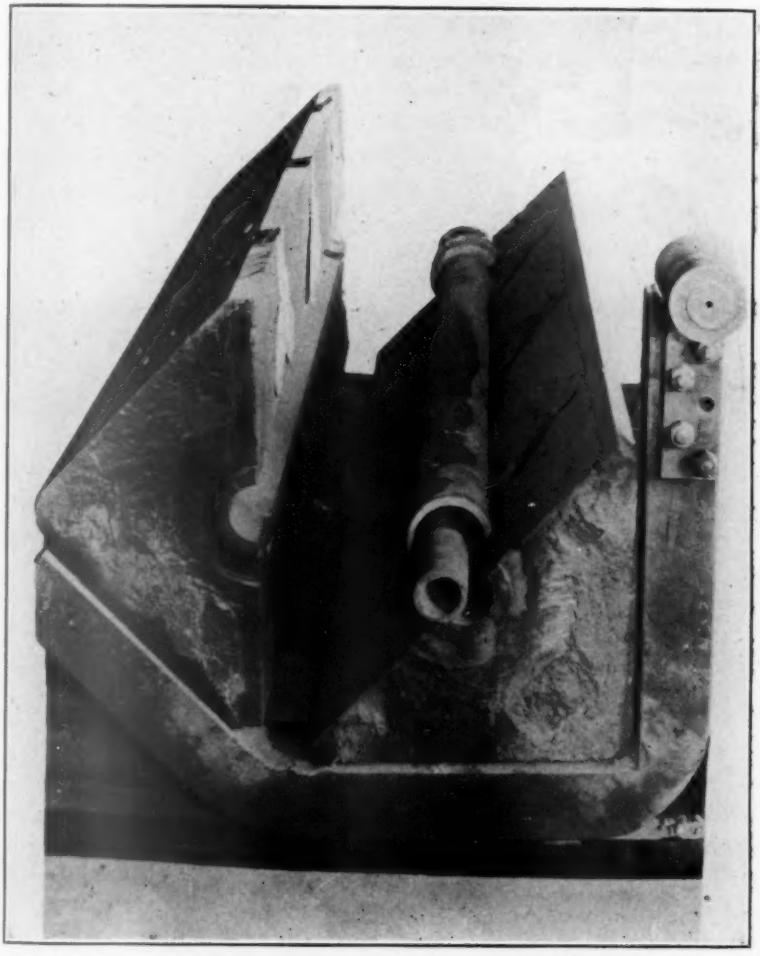


Motors, pumps, valves, piping and reservoir.

which may be trapped in the mold, and so avoid the formation of flat spots at the top of the pipe. The resultant ridge not being prominent is not an objection but rather adds to the strength of the structure.

On one end of each mold is carried an arm rigidly attached to the upper or movable half. This arm extends under the mold and is of such form that when the mold is open it forms a rest for the movable half, holding it in such position as to allow of any work, such as setting cores, removing finished pipes, cleaning,

etc. On the end of this arm is a steel roller which is caused to travel down an inclined plane by the rotation of the table carrying the mold. This inclined plane is arranged to receive the roller at its higher position when the mold is open, and to guide it



Open mold, showing finished pipe.

smoothly to its lower position, by this means closing the mold without shock or jar to disturb the core. This inclined plane constitutes the closing device.

Each end of the mold is provided with rings or bushings which are used to support the core arbor in a precisely central position in the cavity of the mold, so that the pipe when finished shall have uniform thickness of metal at every point.

The core arbor consists of a cast-iron hollow cylinder somewhat longer than the pipe to be cast and about three-quarters of an inch less in diameter than the inside diameter of the pipe. It is perforated throughout most of its length by small holes to allow any gases formed by contact with the molten metal to pass into the arbor and so have free vent to the air through the ends of the same.

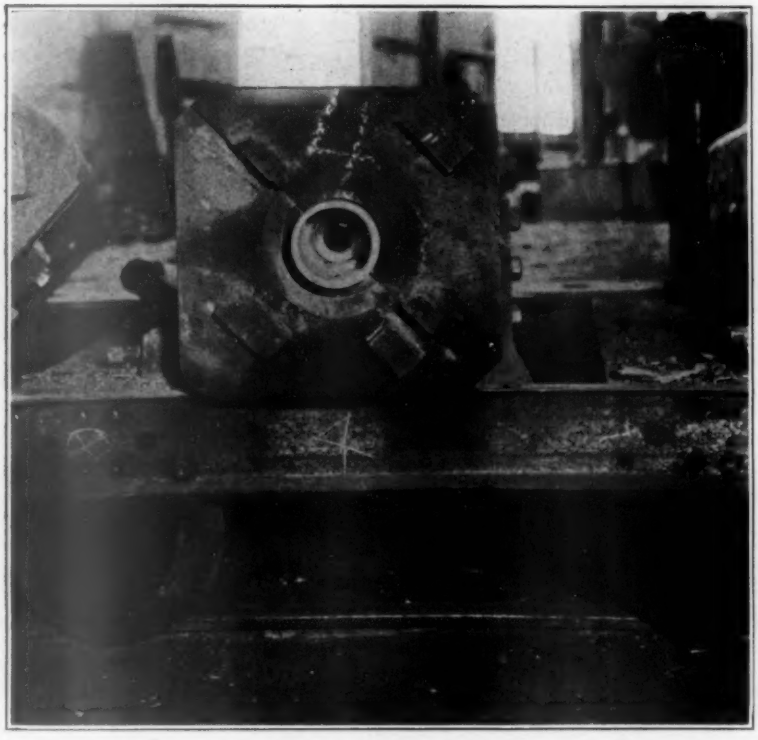
Each end of the arbor is accurately machined to fit the rings or bushings in the ends of the molds.

The core is made by placing the core arbor in the core machine, which consists of a support for the ends of the arbor, semicircular in form, and of a diameter to fit the arbor ends; a shaking screen arranged to sift sand, and a guide to drop it upon the arbor, and a knife, so shaped as to form the sand to the outline of the inside of the pipe.

The core arbor after being wet thoroughly is placed in the end supports and rotated by a crank-shaped piece of iron held loosely in one end, by an operator. At the same time another operator shakes a sieve suspended over the arbor and previously filled with sand, tempered to the proper degree with water. This sieved sand is caused to fall directly upon the wet, rotating arbor and clings to it. The surplus sand is scraped away by a steel knife held at the proper distance from the arbor to make the finished core of the diameter and shape required. When sufficient sand is on the arbor to make a full and complete core (which requires about five seconds) the core is lifted from its supports and is ready for use. No further treatment of any kind is needed, and the core is placed in position in the mold, which is then caused to pass the closing device, bringing the upper portion down in place and the mold is ready to receive the metal.

A ladle is provided to receive the metal as it flows from the cupola. This ladle is arranged so that it can take a position high enough to allow the molds to pass freely under it, or it can be lowered into a position between two adjacent molds, so that the pouring spouts or lips of the ladle are very close to the pouring holes of the mold.

As the table rotates and brings a mold, which has passed the closing device, into pouring position the ladle automatically drops into this latter position with the lips close to the pouring holes. The ladle is then tilted to pour by the operator, but in tilting it rotates around a center line which passes through the pouring lips, and hence the points of pouring do not move; and the streams of metal are guided directly into the pouring holes through the va-



Closed mold. Core arbor in place.

rious gates into the mold and fill it completely, compressing any air or gas which may be trapped into the groove provided at the highest point for that purpose. If no gases are trapped, which, strange as it may seem, is usually the case, this groove is also filled with metal and forms a slight rib running the length of the pipe.

When the pouring operation is complete and operator tilts the

ladle back, it automatically rises to its higher position so that the next mold may pass under it and assume the pouring position.

The mold being now filled with metal, is held long enough to allow the metal to set and then opened by passing the opening device, which is just the reverse of the closing device; the roller on the end of arm or mold, being guided up an inclined plane, thereby lifting the upper half or cope side, and swinging it away from the lower or drag side.

The pipe, which is still a bright orange color, is lifted from the mold and placed, after removal of gates, with those previously cast, in piles, to cool slowly, when the core arbor is withdrawn and returned to core machines to be used again.

After removal of the finished pipe from the mold, the loose sand which falls from the core during the handling of the pipe, and any other dirt, loose gates, etc., which may be left in the mold are swept out by air blasts or hand brushes and the mold is ready for another core and another filling with metal.

The method of pouring is very important; in fact, the success of the whole operation hinges very closely upon properly carrying out this scheme. By it is secured equal velocity and pressure of the molten metal as well as simultaneous action. Too much stress cannot be laid upon this feature. The difference between a good pipe and a bad one is the difference between good and bad pouring.

Section of Physics and Chemistry.

(Stated meeting held Thursday, April 9, 1908.)

Methods for Protecting Iron and Steel Against Corrosion.

(A Review.)

By Geo. B. Heckel.

Gentlemen:—This paper should be prefaced by an explanation. The Executive Committee of the Franklin Institute, in their inscrutable wisdom, imposed upon me the duty of addressing you upon a subject regarding which doubtless many of you are better informed than I. I presume that I owe this distinction to my official position as Secretary of the Paint Manufacturers' Association of the United States, and my connection with Committee "E" of the American Society for Testing Materials. I do not, however, pose as an expert or authority on this or any other subject, and therefore I took the liberty of changing the title of the address as originally proposed to me, and shall speak rather in review of the work of others on protective coatings than of my own knowledge of the subject.

Steel has, within a few years, come into almost universal use as a structural material, and with the introduction of reinforced concrete its application promises still greater expansion. Steel, and especially Bessemer steel, is subject to corrosion from atmospheric agencies, and upon our ability to protect it from corrosive attacks depends the permanency of our bridges, our sky-scrapers, the beams and girders of our factories, etc.

Dismissing for the moment all forms of corrosion excepting that form of oxidation popularly known as rusting, it is essential as a starting point to inquire, what is rust and what causes it?

When a steel plate is exposed to an atmosphere charged with

moisture it may or may not rust. The difference is easily observable in ordinary conditions. On some days when the atmospheric moisture is high all exposed steel will quickly show rust stains. On other days when the degree of moisture is equally high, rust will form but slowly, if at all.

There must be a cause for these differences of behavior under apparently identical conditions.

From the facts which follow it would appear to be due to the presence in solution of larger or smaller percentages of carbonic acid, mineral acids from smoke and of ozone. For, as will be shown later, some agencies distinctly promote, while others retard, or completely inhibit oxidation.

Ordinary iron rust is perfectly familiar to everyone. It is a yellowish, reddish or brownish substance and normally consists essentially of hydrated ferrous oxide, though as shown by Dr. Toch, the degree of oxidation and hydration may vary considerably in the same samples of rust, the exterior portions of the layer generally tending more towards a stable oxide and the portions next to the metal being highly ferrous in composition.

I do not intend to review the chemical constitution of rust nor to trace the chemical processes involved. All forms of rust depend for their formation on the fact that oxygen in solution in water enters readily into combination with iron and that carbon dioxide and other acids in the atmosphere may act as promoters and modifiers of the process. The entire subject is discussed at length in the writings of Wood, Toch, Dunstan, Jowatt, Moody, Walker, Cushman, and others, and is summarized in the United States Department of Agriculture, Office of Public Roads, Bulletin No. 30, to which the curious are referred.

Formerly it was supposed that iron immersed in pure water *in vacuo* would not rust; but Whitney and Cushman have conclusively shown that iron does pass into solution in pure water without the presence of free oxygen or other agent, and this fact opens the way to an entirely new method of protection, which we shall consider at greater length as we proceed.

Hitherto the problem of protection has been regarded as merely a problem of isolation,—the exclusion of moisture and oxygen, and doubtless if we could effectually and permanently exclude the agents of rust we could preserve our material indefinitely.

Two methods of isolation are generally employed, either sepa-

rately or simultaneously. The interposition of a film of paint between the surface of steel and the atmosphere or the deposition of a firmly adherent film of non-corroding metal in the same position, as in the coating of roofing sheets with tin and lead and the deposition of a film of zinc in the so-called "galvanizing" processes.

Regarding the latter, which may be very briefly considered, it is worthy of note that the new process for coating a surface of steel with a film of zinc by subjecting the steel plate to a low heat in contact with zinc dust, seems, from the meagre reports at hand, to give promise of excellent results in the future. In this process, it is said, the zinc penetrates the steel to an appreciable extent and forms a continuous film of metal over its surface. If this process shall be made commercially available there is no apparent reason why steel so coated shall require further preliminary protection, the deficiency of ordinary galvanized iron being apparently due to the imperfect continuity of the zinc coating.

A steel surface properly covered with a coating of metallic zinc, and insulated from contact with other metals, should need no further protective coating for a long period. Mr. Stone, of the New Jersey Zinc Company, tells me of galvanized roofing plates that remained in service for sixteen years and then were put out of service only because the building was demolished.

But manufacturers have learned how to economize zinc since those days, and the zinc coating no longer fully protects because it is too thin and is not continuous.

Let any one compare a piece of coated telegraph wire with a piece of ordinary galvanized plate by subjecting them for a time to the action of moisture under identical conditions and he will at once recognize the difference between complete and incomplete coating. It would also be interesting to compare with these a specimen of the Sherardized steel before referred to.

Still another method of coating steel with metallic zinc is the electrolytic process, of which I have samples here. Advantages of economy as well as of purity and homogeneity of coating are claimed for this electrolytical or cold process galvanizing. The claim of superiority at least would seem to be justified by the results with these small samples, which have been immersed in water for over three months without showing signs of rust. One specimen had its uncoated end protected with paraffine wax, the

other was not so protected. The process is said to be applicable to any size or form of steel. (Show specimens.)

What I wish here to emphasize is the fact that a properly galvanized metal surface needs for long periods no additional protection. Paint may be applied for decorative purposes, but is unnecessary at the beginning for any other use.

While we are upon the subject it might be worth while to note in passing, the proposition made some years since by certain engineers that masses of zinc in electrical contact with the steel be buried in the foundations of our sky-scrapers. The idea, of course, was that the zinc being the electro-negative member would be corroded, while the steel would be preserved.

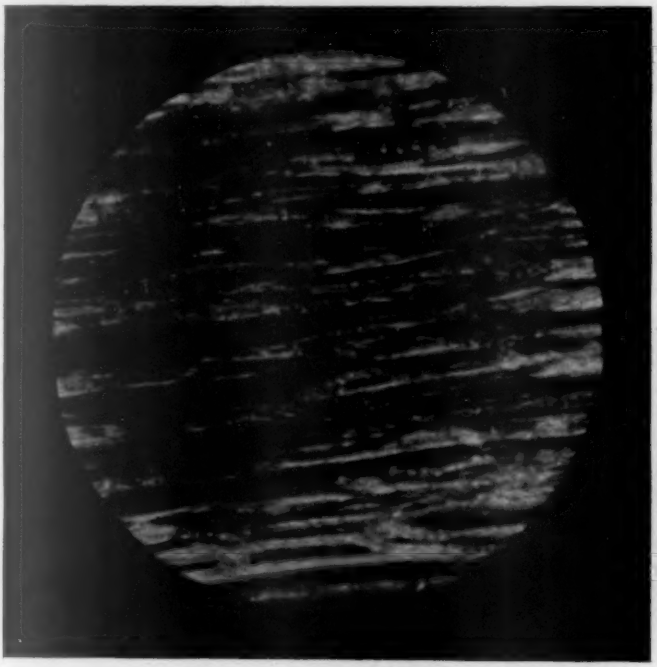
For the benefit of our mining and smelting interests we might wish to see this method generally adopted, with provision for the renewal of the zinc as corrosion proceeded.

The problem of protection by painting metallic surfaces comprises several important factors, differing materially from the conditions presented by a surface of wood. In the latter we have a more or less absorbent or porous surface, every minute aperture of which affords a hold for the film of paint. Furthermore the coefficient of expansion for any wood under change of temperature is so low as to be negligible. If we can exclude moisture from the painted wood, the protective coating is subject to practically no stresses or strains.

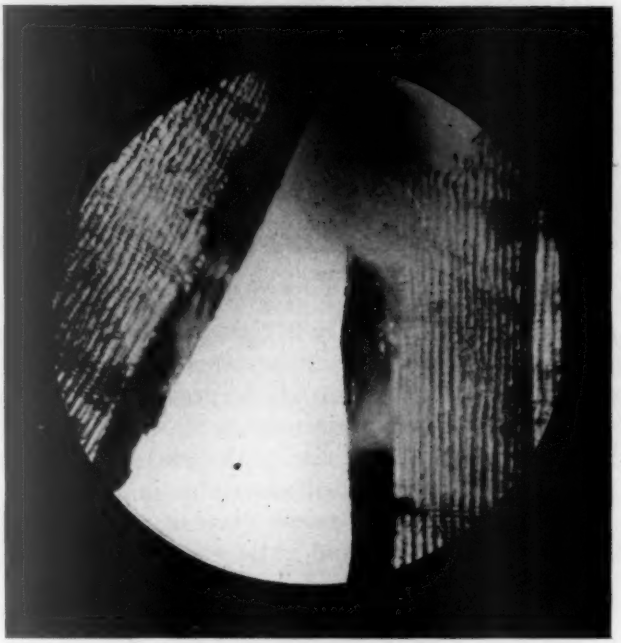
Steel, on the other hand, presents to the eye an intact surface. It is only under magnification that we detect its actual irregularity. Two forces probably tend to hold a film of paint in place on such a surface: First, the hold of microscopic projections from the under surface of the film on the irregularities of the metal surface, and second, the force of cohesion or atmospheric pressure.

The coefficient of expansion for steel, within the limits of range for atmospheric temperature, is high—far higher than that of any known paint film. This deficiency in the latter must be compensated for by elasticity. The film must be sufficiently elastic to accommodate itself to the constantly changing area of the surface to which it clings, without rupturing the film itself or the minute projections by means of which it clings to the surface.

Finally, since moisture, acid, ozone and perhaps other atmospheric agencies are at least the principal causes of rust, the pro-



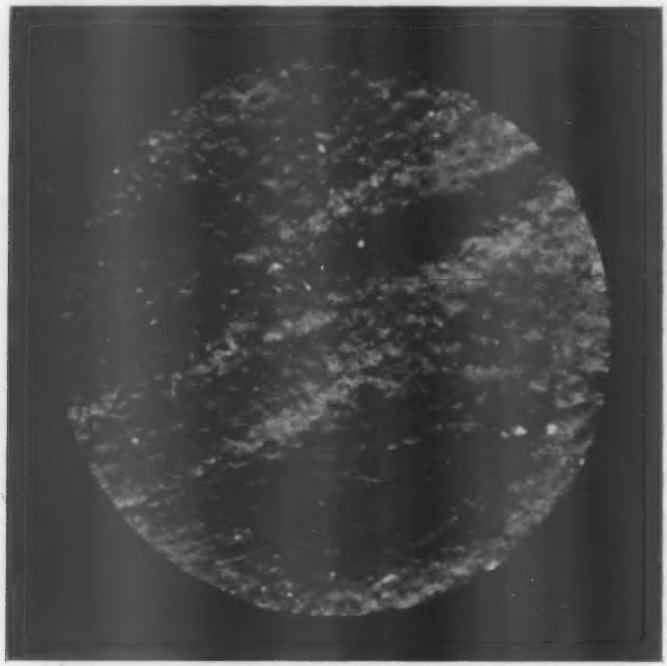
Micro-photograph of wood surface.



Micro-photograph of paint films on wood.

tective coating must, insofar as possible, be impermeable by vapors and gases.

From the stated difference of the two surfaces it is readily deduced that a paint to penetrate and secure a firm hold on the microscopic irregularities of a steel surface must be different from a paint intended to penetrate and adhere to wood, while the rigidity of the one as contrasted with the softness of the other would indicate other differences.



Micro-photograph of steel surface.

For example, Mr. R. S. Perry has propounded a very interesting theory in which a parallel is drawn between the paint film and concrete, and from this he deduces the desirability of three determining sizes in the pigment particles to fill voids. But bearing in mind the extremely minute size of the projections and apertures, it would seem reasonable to assume that in the undercoating at least of a protective paint for such a surface the pigment particles should be extremely fine; and furthermore, as it is exclusively

the vehicle and never the pigment that imparts elasticity to the coating, that the elastic vehicle should be in excess.

The Scientific Section of the Bureau of Promotion and Development, Paint Manufacturers' Association, under the direction of Mr. R. S. Perry, is doing very much valuable work in the way of furnishing technical data, and among other information it has furnished measurements of the particles of several pigments in common use. Following are the measurements given me:

White Lead (Hydrocarbonate)	.000074	.033
White Lead (Sublimed Lead)	.00003	very uniform
Zinc Lead	.00004	" "
Zinc Oxide	.00002	" "
Carbon Black	.007	.0007
Lamp Black	.00009	
Mineral Brown	.06	.007
Red Lead	.006	.08
Silica	.00024	.0016
Calcium Carbonate	.00012	.0016
Barytes	.00008	.0004
Gypsum (Thin Plates)	.00032	.0019
Asbestine (Long Rods)	.00016	.0032
China Clay (Thin Plates)	.000016	.0028

These measurements represent the dry pigments as they come upon the market. With some of them chemical changes effected in combinations with oil acids profoundly modify these mechanical factors; with others, keeping in mind the conditions to be met, extremely fine grinding in the process of manufacturing into paint would seem to be indicated as essential.

Mr. Job, in a paper read before this body some two years since, admirably illustrated from practical experience the necessity of a high degree of comminution in protective paints for metal surfaces. The differences in the behavior of the paints contrasted by Mr. Job would seem to depend first upon the excess of vehicle (the elastic element) in paints compounded with finely ground pigments, and secondly in the smaller area of the voids between the particles of pigment in the paint film. For, as Dr. Dudley has so often and so admirably demonstrated, linseed oil is to a surprising extent permeable by moisture, and it is the province of the pigment, to a large extent, to compensate for this quality of linseed oil, by presenting a series of impenetrable layers of pigment to the atmospheric vapors.

In the early days of English and Scotch steel ship building it was the custom—which still prevails to some extent—to give all steel members, while hot, a shop-bath of linseed oil. Something like this had evidently been done with the steel used in the Havre-de-Grace bridge, on which Committee "E" is now experimenting. In that case it did not prevent rusting, but entailed much labor to remove it. The coating was not protective and had become so brittle that it would have formed a very unsafe foundation coat.

In the practice of some firms it is the custom to give all structural steel a shop-coat of red lead and linseed oil. This practice is far less objectionable, as red lead does at least make a good foundation for subsequent painting. As to the relative merits of red lead and other pigments, the subject is too wide for me to handle. Perhaps if red lead were always mixed fresh on the ground and applied while freshly mixed, there would be much less room for controversy.

We now come, in the course of our review, to one of the most interesting developments of modern paint chemistry—a development which may eventually solve our problem, leaving nothing for future workers, or which may prove a mere *ignus fatuus* of science, like so many apparent discoveries which have preceded it.

During the year 1905, Dr. Allerton S. Cushman, of the Department of Agriculture, in the course of certain investigations connected with the corrosion of fence wire and steel culverts, made a special study of the curious fact that the corrosion of steel is inhibited for a time by treatment with chromic acid or a soluble chromate. Other investigators had from time to time referred to this peculiar condition of passivity, but so far as I know, Dr. Cushman was the first to investigate its causes and to supply a satisfactory explanation. His explanation briefly depends upon the modern theory of solutions. The familiar phenomenon of rusting is due to electrolysis. The free hydrogen ions in water exchange places with the iron, transferring their electrical charges and changing to the atomic condition. The iron passes into solution and is attacked by the oxygen of the water, further hydrogen being ionized in the process for further attack, and so on indefinitely.

The complete theory is beautifully demonstrated and illustrated in Bulletin No. 30, issued from the Office of Public Roads of the Department of Agriculture, and every one interested in the

preservation of metals should read this bulletin, because it is full of noteworthy information and suggestion. It is only fair to say that Dr. Cushman's deductions have been attacked and that his theories have not met with complete acceptance. Nevertheless he has certainly demonstrated some important facts, whatever may be the ultimate fate of his explanations.

He has, for instance, positively shown that chromic acid and its compounds will inhibit the corrosive action of moisture on iron. He has shown that iron passes into solution in pure water, and he has shown more recently that the mere presence of certain chromates together with steel in water inhibits oxidation.

The results obtained by Dr. Cushman in the latter field are summarized in a letter to me under date of March 11th, as follows:

"I have been conducting a long series of experiments studying the action of various pigments together with water and oxygen on steel. I find that, under the conditions of my experiments, the ordinary commercial mixed pigments fall naturally into three classes:

"(1) Those which prohibit or largely inhibit corrosion.

"(2) Those which have no action one way or the other, and from this point of view are therefore inert.

"(3) Those which stimulate corrosion.

"I am not yet ready to give out the details of the experiments, but I will be very glad to give you one or two points which I should be pleased if you would bring out. My observation that chromic acid and certain of its compounds act as inhibitives has led to a great many experiments by other workers along the same line. Now, I have found that the chrome compounds which are on the market vary very much in their action. Some of them show up as strong inhibitors, while others go to the opposite extreme and actually stimulate corrosion. Referring only to the labelled names of the pigments which I have tried, I find among the good ones, and in the order cited: Zinc chromate, American Vermilion, chrome yellow orange, chrome yellow dd. Among the bad ones, and also in the order given, I find: Chrome yellow medium, chrome green, chrome red. And very much the worst of all is chrome yellow lemon.

"I presume that the difference is due to impurities that are present in the bad pigments. For instance, I believe that the lemon chrome yellow contains some salt or compound which had been

added in order to keep the reaction acid during the process of manufacture so that the bright yellow shade will be preserved. You will understand, of course, that when I speak of 'good' and 'bad' pigments I mean merely in their relation to inhibiting or stimulating corrosion in the presence of water, and this characterization has nothing whatsoever to do with physical state or properties when mixed with oil. It is, however, important in my opinion that these differences should be noted in advance, for if an experimenter should happen upon lemon chrome yellow and obtain bad results with it he might unthinkingly conclude that the whole principle of the chrome protection was at fault."

In explanation of Dr. Cushman's results with the lemon chrome it should be said that this shade is commonly produced by the presence of lead citrate or other similar lead salts and that it is not a pure lead chromate.

Dr. Cushman's remarks regarding the starting of independent investigators is undoubtedly true, and since the publication of his address to the American Society for Testing Materials last June nearly every technical chemist in the country has had a bottle of steel turnings in chromate solution standing convenient for observation.

It occurred to me, for instance, that in estimating the effect of the various atmospheric agencies in corrosion it would be instructive to run a series of duplicate tests in which the effects of the various atmospheric influences should be segregated.

Accordingly I requested Mr. Gardner, of the Scientific Section of the Paint Manufacturers' Association, to ascertain for me with small steel plates cut for me from the middle of the same bar—

1. Whether a steel plate immersed in distilled water in vacuum will show rust;

2. Whether a similar plate immersed in distilled water charged with pure oxygen only, will develop rust;

3. Whether a similar plate immersed in distilled water charged only with ozone will develop rust;

4. Whether a similar plate immersed in distilled water charged only with atmospheric air free from all substances excepting oxygen and nitrogen will develop rust;

5. Whether a similar plate immersed in distilled water saturated only with atmospheric air containing a small percentage of ammonia gas will develop rust;

6. Whether a similar plate immersed in distilled water containing only atmospheric air with a small percentage of carbonic acid and nothing else will develop rust;

7. Whether a similar plate immersed in distilled water containing only atmospheric air with small percentages of ammonia and carbonic acid will develop rust:

8. Whether in all the foregoing tests a current of electricity passing through the plate will stimulate rusting.

In each case I requested that the ratio of rust development be determined.

These determinations were made for me, the tests lasting for one month. Mr. Gardner in his report details the method of procedure, which was technically correct. The complete report is available for anyone who cares to see it, but I shall content myself with tabulating the results: (*See Appendix.*)

Test No.	Medium.	Loss.	Remarks.
1	Distilled water boiled	0.0482	
1-A	Same with electric current	0.087	
2	Distilled water and oxygen	0.0601	
2-A	Same with electric current	0.1211	
3	Distilled water and ozone	0.0768	
3-A	Same with electric current	0.1155	
4	Pure air oxygen and nitrogen	0.0492	
4-A	Same with electric current	0.0911	
5	Pure air—with ammonia: Oxygen, nitrogen and ammonia	0.0406	Little oxide precipitated. Color dark.
5-A	Same with electric current	0.0758	" " "
6	Pure air—with carbon diox: Oxygen, nitrogen and carbonic acid	0.103	Color of oxide brighter than any of foregoing.
6-A	Same with electric current	0.1941	" " "
7	Pure air with ammonia and carbonic acid	0.0921	" " "
7-A	Same with electric current	0.1876	" " "

It will be seen from this summary that in every case the passage of an electrical current from a sal ammoniac cell, averaging 1½ volts, very materially assisted corrosion. Mr. Gardner also reports that of his own initiative he connected the two ends of a steel plate in distilled water by a copper wire joined outside of the bottle, and that in this case also corrosion was increased. He believes this increase to be due to galvanic action.

It then occurred to me that it would throw further light on the

subject if these experiments were duplicated precisely, with the addition of potassium bichromate to the water in each case. Accordingly Mr. Gardner was requested to clean the original plates and duplicate the tests after adding sufficient bichromate to make a one per cent. solution. After thirty days no rust had appeared in any of the test bottles, even the electric current having failed to start corrosion.

These experiments, I think, prove conclusively that the presence of a soluble chromate will inhibit corrosion, and beautifully support Dr. Cushman's claims.

Some years since, Dr. Dudley in the course of his investigations on steel discovered segregations of manganese which acted as centres of electrolytical corrosion. This discovery gave birth to a whole school of manganese writers—but little further has been discovered along that line.

At the present time, however, Dr. Cushman is investigating this subject also and has secured results entirely confirmatory. In fact at this date there would seem to be no room for doubt that the existence in steel of materials of potentially unequal electrical energies is one of the chief promoters of corrosion. Steel low in manganese, carbon, silicon, etc., does not corrode so readily nor so rapidly as a steel showing higher percentages. It has been shown to be possible by mechanically combining pure iron and pure manganese in a finely divided state to cause electrolysis and the visible liberation of hydrogen by merely dropping the mixture in water.

Other investigators have found great differences in the behavior of different steels in the same conditions. Mr. Wirt Tassin, of the National Museum, has suggested that these differences may be due to differences in the micro-structure of the steels, dependent largely upon the temperature at which they are finished.

With a view to obtaining some light on the question, Dr. Dudley kindly furnished me with some steel borings taken from the same piece of mild boiler plate, the first lot from the plate as received from the maker, the second lot after heating and quenching. Portions of each lot were placed in distilled water and in two per cent. solution of potassium bichromate. They are here for examination. In both cases the borings in distilled water show rust, while in neither case does the bichromate test show any change. This test, so far as it goes, would seem to prove conclusively that the condition of the carbon in the steel has no de-

cided influence upon the inhibitive power of the bichromate. (Specimens shown.)

As I remarked at the outset, I do not profess myself an authority on this subject. In fact, so far as I can learn, the subject is one in which thus far many opinions have been expressed and many theories advanced, but few fundamental technical facts established, excluding purely scientific laboratory researches, such as Walker's and Cushman's.

What has been so far accomplished has been largely the result of empirical observation. This hap-hazard observation has, however, brought forward some significant data which it remains for the trained investigator to classify and from which he may gain an inkling of the basic governing principles.

Sabin, for example, long since demonstrated the fact that a coating of tough varnish applied hot to iron pipes prevents rusting in a marked degree. Toch has pointed out the fact that steel rods imbedded for a long time in concrete showed little corrosion on removal. Several observers have proved that oxide of zinc, lamp-black and some other very finely divided pigments under certain conditions are highly protective. The protective value of red lead freshly mixed before application has long been recognized. Scott, in an address before the Master Painters' Association of Wisconsin, stated that steel shutters painted for the J. I. Case Company with basic lead chromate gave protection twice as long as any other material used, etc., etc.

These and many more familiar instances would seem to indicate that we are at last in a position to lay down tentatively, at least, three conditions as necessary for the protection of steel from corrosion. We will briefly consider these conditions:

First. *Isolation.*—The surface must be shielded as effectively as possible from the access of moisture and atmospheric agencies. This involves the necessity for a paint coating less permeable than linseed oil alone; sufficiently elastic to accommodate itself to the continual expansion and contraction of its support. This coating must furthermore be permanently adherent and must retain its elasticity during a reasonably long time. Fine grinding of the pigments used, the addition of China wood oil, varnish gums, and perhaps even a heavy neutral petroleum oil, used under proper conditions, may help us towards this end.

Second. *Insulation.*—If it be found—and it seems to be well

established—that the passage of an electric current through the members of a steel structure, promotes corrosion, it is evidently a part of our task to reduce as far as possible this element of danger.

Third. *Immunization.*—This is to most investigators a new field with unknown possibilities. If it be found, as indicated in Dr. Cushman's experiments, that the mere presence of certain pigments in the paint film tends to retard corrosion, the converse is also probably true, that the presence of other pigments tends to facilitate it. After the investigators have finished their work of classification and have determined for us, in Dr. Cushman's phrase, which are the "good" and which are the "bad" pigments, it will remain for the paint technologist to apply the knowledge to practice. The pigments given in Dr. Cushman's list are all expensive, but it is probable that if there were any considerable demand for zinc chromate, for example, the price would soon fall to a moderate figure, due to increased production.

I was personally so much impressed with Dr. Cushman's original paper and with Mr. Scott's experimental confirmation following so soon after, that having occasion to supply a formula for a protective paint for use by the New Jersey Zinc Company I suggested the following:

40 lbs. American Vermilion,
10 lbs. Red lead,
5 lbs. Venetian red.

Zinc oxide and lamp-black to produce the required tint or shade. Grind in 1 1/3 gallons of raw linseed oil—increasing the quantity as required for added zinc oxide or lamp-black—and $\frac{1}{8}$ gallon crusher's dryer. For use, thin with raw oil and very little turpentine or benzine.

This is Scott's formula slightly modified. I am inclined to believe that the substitution of zinc chrome for the American Vermilion; of any high-grade finely ground iron oxide for the Venetian red; and of American Vermilion for the red lead, would improve the protective value of the formula, while I also believe that the addition of a very little kauri gum varnish, if zinc oxide is used, would be found advantageous, and that the substitution of a certain proportion of China wood oil for some of the linseed oil would improve the wearing qualities of the paint.

Dr. Cushman in reviewing the formula, points out two dangers

confronting us when we attempt to base an inhibitive formula on commercial products. The first is that all carbon pigments, excepting pure graphite, may contain sulphur compounds easily oxidizable to sulphuric acid when spread out as in a paint film. The second is the probability of variation in the composition of basic lead chromate or American Vermilion. Because of these facts, as he points out, it is necessary, before selecting any particular pigment for its inhibitive quality, to ascertain that it is free from acids or acid forming impurities. As a result of his own experiments he recommends the substitution of Prussian blue for the lamp-black in my formula and lays down as a safe rule in the formulation of inhibitive paints, a careful avoidance of all potential stimulators of the hydrogen ions and consequently of any substance which might develop acid; preference being given to chromate pigments which are to some extent soluble in water and to other pigments which in undergoing change tend to develop an alkaline rather than an acid reaction. Calcium sulphate, for example, in any form (as a constituent of Venetian red, for example), he deems dangerous to use because of the possibility of its developing sulphuric or sulphurous acid. Barium sulphate, on the other hand, he regards as practically safe, because of its well-known chemical stability.

In my own formula the substitution of zinc chrome for the larger proportion of American Vermilion, as suggested, would replace an indefinite by a definite chromium compound.

Barium chromate has also been shown by Dr. Cushman's experiments to be an inhibitor of high power, and I have suggested the possibility of producing a good inhibitive chromate by the simultaneous precipitation of the chromates of zinc and barium. Similarly a very brilliant and opaque chromate can be obtained by the simultaneous precipitation of the chromates of lead and zinc on a zinc oxide base. Furthermore, as Prussian blue has been found to be at least safe, it would seem to be possible to produce an inhibitive chrome green by the simultaneous precipitation of the blue and yellow on a barium sulphate or a silicate base. The entire subject is open to investigators and it is to be hoped that definite knowledge will rapidly accumulate as a result of their work.

As I began I close: I am not an authority on this or any other subject, but if I have been able profitably to direct your attention

to the valuable work which investigators—notably Dr. Cushman, Dr. Gustave W. Thompson, and the Paint Manufacturers' Association—are conducting in this field, I shall be repaid for my time and you for your patience, for which I thank you.

APPENDIX.

REPORT ON TESTS OF STEEL PLATES.

(Made to the Paint Manufacturers of the United States.)

By H. A. Gardner.

Fourteen steel plates 1½" x 1" were received at this Laboratory, in the rough condition as sheared from the strip. These plates were perfectly cleaned to insure the absence of incidental grease. They were all numbered consecutively by scratching them, and all well washed in ether and then dried at 100 degrees in an air bath for an hour. They were then taken and placed in a desiccator, and when they had reached the temperature of the room they were weighed down to one-tenth of a milligramme. The plates were then ready for test.

A series of bottles of one litre capacity, with rubber stoppers, were selected as the vessels in which to conduct these tests, and these bottles were labelled with numbers corresponding to those upon the steel plates.

These tests extended over a period of one month, at the end of which time the rust was considerable. The plates were then partially removed from the water, and the rust upon the same was easily removed by the aid of filter paper, and dropped back into the solution. The plates in this thoroughly cleansed condition were removed, washed in distilled water and finally in ether, and then placed in an air bath and dried at 100 degrees before weighing. The difference in the weight before and after these tests represents the amount of iron eaten away, or formed into rust by the action of the medium in which these plates were immersed.

TEST NUMBER 1.

Bottle No. 1 was filled with distilled boiling water, to the surface, after which the plate was placed in the bottle, and the rubber stopper securely pressed down. The cooling of the distilled water caused a slight loss of volume which left a vacuum of about ¼ inch between the surface of the liquid and the stopper.

TEST NUMBER 1-A.

The same experiment was conducted in Bottle 1-A with a current of electricity passing through the liquid.

TEST NUMBER 2.

Bottle No. 2 was filled with distilled water charged with a current of oxygen generated by heating mercuric oxide (the gas being washed in a bottle containing water); the plate was then immersed in the water and the stopper securely pressed down.

TEST NUMBER 2-A.

The same experiment was conducted in Bottle No. 2-A with a current of electricity passing through.

TEST NUMBER 3.

Bottle No. 3 was filled with distilled water and a current of ozone passed through for about thirty minutes. The ozone was generated by attaching two dry cells to a Rumkorff coil, the induced currents from which were passed to an ozone tube, the ozone being drawn over by aspiration and then passed through the water. The ozone developed by this apparatus was very strong, and the water must have absorbed or taken up considerable of the same because the odor of ozone was very apparent.

TEST NUMBER 3-A.

The same experiment was conducted in Bottle No. 3-A with a current of electricity passing through the liquid.

TEST NUMBER 4.

Bottle No. 4 was filled with distilled water charged with atmospheric air, free from all other substances, excepting oxygen and nitrogen. The atmospheric air was drawn in through a bottle containing caustic potash to absorb the ammonia and then through a bottle containing soda lime to absorb the carbon dioxide gas, and then in its pure condition, containing nothing but nitrogen and oxygen, was passed through the water.

TEST NUMBER 4-A.

The same experiment was conducted in Bottle 4-A with a current of electricity passing through the liquid.

TEST NUMBER 5.

Bottle No. 5 was filled with distilled water and atmospheric air passed through for about thirty minutes, after having been passed through a bottle containing soda lime to free it from carbon dioxide. This atmospheric air was pure with the exception of a normal percentage of ammonia gas. A current of weak ammonia gas was passed through for a second to insure the presence of same.

TEST NUMBER 5-A.

The same experiment was conducted in Bottle No. 5-A with a current of electricity passing through the liquid.

TEST NUMBER 6.

Bottle No. 6 was filled with distilled water, and atmospheric air was passed through for about thirty minutes, after having freed this atmospheric air from the ammonia, by passing it through a bottle containing caustic potash. This atmospheric air contained the normal percentage of carbonic acid. A current of carbon dioxide was passed through for a second to insure the presence of same.

TEST NUMBER 6-A.

The same experiment was conducted in Bottle No. 6-A with a current of electricity passing through the liquid.

TEST NUMBER 7.

Bottle No. 7 was filled with distilled water which was saturated with atmospheric air containing normal percentages of ammonia and carbonic acid. The plate was then immersed in this liquid.

TEST NUMBER 7-A.

The same experiment was conducted in Bottle No. 7-A with a current of electricity passing through the liquid.

The current of electricity used was very weak and was obtained from an ordinary sal ammoniac cell averaging 1½ volts, and this current was passed through a main line from which branches were made direct into the bottles and direct to the plates by contact, each plate having connection with a kathode and anode respectively. After the first day of these tests the action of the electric current was very apparent and considerable rust was observed, the water in these bottles being turned to a light yellow color, which after a month was very decided. The amount of rust observed on the plates not charged with electricity was less apparent throughout the test. For my own benefit, I placed in a bottle containing absolutely pure distilled water a small plate of steel, connected at either end with pieces of copper which were joined outside the bottle, thus forming a circuit. This test developed an amount of rust equal to that formed in any of the bottles in the foregoing tests with electricity, and I believe this was caused by galvanic action.

It is interesting to note that a casual observation of the amount of rust contained in the bottom of the bottles corresponds to the amount determined by gravimetric work.

Bottles Nos. 1 and 4 from their appearances seem to contain less oxide of iron than the other bottles with the exception of Bottle No. 5, and this is borne out as you will see by the appended data. Bottles Nos. 6 and 7 seem to contain a very large amount of oxide of iron. This is also borne out by the data. This oxide of iron in Bottles Nos. 6 and 7 has a much brighter appearance than that contained in the other bottles. In Bottles No. 5, in both cases, with or without electricity, there is very little iron oxide, and what there is seems to contain a magnetic oxide, the formula of which is Fe_3O_4, and is very dark in color. Although considerable of this

was formed it seemed to have formed upon the metal as a black coating, and evidently has served to prevent the oxidation of the iron and the formation of ferric oxide. The water in both of these bottles is very clear, with the exception of a dark sediment.

The following table will show the weight before and after test, also the amount of iron disintegrated by the action of the solution:

Test No. 1.	*Test No. 1-A.*
63.701 gm. before test	63.12 gm. before test
63.653 gm. after test	63.003 gm. after test
.0482 gm. loss	.087 gm. loss
Test No. 2.	*Test No. 2-A.*
65.1831 gm. before test	64.7551 gm. before test
65.123 gm. after test	64.634 gm. after test
.0601 gm. loss	.1211 gm. loss
Test No. 3.	*Test No. 3-A.*
63.1248 gm. before test	63.8055 gm. before test
63.048 gm. after test	63.69 gm. after test
.0768 gm. loss	.1155 gm. loss
Test No. 4.	*Test No. 4-A.*
64.3932 gm. before test	65.0400 gm. before test
64.344 gm. after test	65.95 gm. after test
.0492 gm. loss	.0911 gm. loss
Test No. 5.	*Test No. 5-A.*
63.0806 gm. before test	61.8858 gm. before test
63.04 gm. after test	61.81 gm. after test
.0406 gm. loss	.0758 gm. loss
Test No. 6.	*Test No. 6-A.*
63.813 gm. before test	65.6741 gm. before test
63.71 gm. after test	65.4800 gm. after test
.103 gm. loss	.1941 gm. loss
Test No. 7.	*Test No. 7-A.*
65.5421 gm. before test	63.8975 gm. before test
65.45 gm. after test	63.7099 gm. after test
.0921 gm. loss	.1876 gm. loss

FUNGUS CHECKS THE RAVAGES OF BLACK HILLS' TIMBER BEETLE.

The bark beetle which for several years has been working havoc in the valuable pine timber of the Black Hills, S. D., has apparently been given a check by a fungus which finds in the dying trees a congenial place of lodgment, and at the same time kills the beetles in the bark. There is hope that the worst of the scourge in that region is passed.

For ten years this beetle has been sweeping through the Black Hills forests, every year invading fresh areas. The total amount of pine destroyed by it is reckoned at no less than one billion feet board measure. At the present stumpage price of green timber in South Dakota this loss

would amount to $6,000,000. It now appears that its maximum destructiveness was reached about two years ago, and it is now on the decline.

Two years ago the discovery was made that a fungus was at work in the timber killed by the beetles, in which the broods were passing their infant stages preparatory to taking flight to new forests. It was noted at that time that the fungus was fatal to the young beetles, but the full extent of the work done by the fungus has just been made known in a report covering investigations of many months by the Forest Service.

The fungus is a "bark-peeler." Experts have claimed all the time that the beetles could be checked if some way could be found to peel the trees in which the young broods are harboring. They live in the inner bark and next to the wood. When the bark is separated from the wood their galleries are laid open and they die. Efforts have been made in the affected districts to peel standing trees. Machinery has been made for that express purpose, and trunks were stripped to a height of twenty feet. But so large were the affected areas that the few trees peeled were not a drop in the bucket.

Efforts were made at different times to cut the dying timber. Tracts were sold to mill men, and large quantities were cut, but not enough to have any appreciable effect on the beetle invasion. Woodpeckers helped the work along. They flocked to the dying trees by hundreds and stripped them of their bark and devoured the young beetles by the million. But that was not enough. The pest had gained such headway that it was beyond the power of barkpeelers, log cutters, and woodpeckers.

Meanwhile the peculiar fungus was gaining headway and getting in its work. It appears in the form of a grayish slime between the bark and the wood. It makes the bark loose and it falls, leaving the trees bare, and bringing down the multitudes of young beetles to their death; or, if the bark still hangs on the trunks, the effect on the beetles is equally fatal, for they die in their galleries and larvæ mines.

The habits and life history of this bark beetle render it defenseless when attacked by the fungus. The parent beetle bores a gallery several inches long in the inner layers of bark, grooving the wood. Eggs are deposited at intervals along both sides of the gallery, often as many as 60 or 70. These eggs hatch, and while in the larvæl state, they bore short galleries at right angles to the parent tunnel. They remain there a year, eating and growing. Their depredations kill the most vital part of the tree—the cambium, though the tops and needles do not succumb at once, and it is at that stage that the fungus appears and brings the career of the beetle brood to a close.

In normal conditions it probably finds a few lightning-struck trees in the proper decline to suit its purposes, or it may attack storm-thrown timber, but it is not numerous enough to kill trees, and its invasion cannot gain headway. But when some unusual condition—such as caused by a hurricane sweeping over a large timber area—provides a start, the beetles may increase in numbers until they are able to attack vigorous trees and kill them, and in fact when the epidemic is at its height they almost invariably attack living trees. That is what has happened in the Black Hills. The invasion continues until some enemy reduces the beetles below the point where they are able to kill timber. That puts an end to the invasion. This is, apparently, what the fungus is accomplishing in the Black Hills at this time.—Forest Service U. S. Dept. of Agriculture.

(Stated meeting held Thursday, March 18, 1908.)

Is the Ether a Dispersive Medium?*

By Paul R. Heyl,

Professor Central High School, Philadelphia.

In the Boyden Prize Memoir, published in the *Journal* for August, 1907, it was shown that over a range of the spectrum comprised between 468 $\mu\mu$ in the blue and 300 $\mu\mu$ in the ultra-violet the speed was constant to the extent of one point in two hundred and fifty thousand. M. Charles Nordmann has recently published (Comptes Rendus, tome 146, Nos. 6 and 8, 1908) some experimental researches which seem to prove that there is, reduced to the same terms as those of the Boyden Memoir, a difference of speed of one part in a million between the red and the blue rays of the visible spectrum. This remarkable result deserves some little discussion.

M. Nordmann's researches were based upon exactly the same method as that of the Boyden Memoir, namely, the spectrophotometric study of the star Algol near its minimum. Mr. Nordmann's work was independently conceived and begun before the publication of the Boyden Memoir. Moreover, M. Nordmann confined his attention to the visible part of the spectrum, while the invisible part was the point of special attack in the Boyden Memoir.

This being the case, M. Nordmann was able to use the very accurate method of visual comparison, comparing the image of Algol and that of an artificial star through a color screen by means of a polarizing photometer. The Boyden Memoir was compelled to use a photographic method, which (according to the limit of accuracy claimed by M. Nordmann) was about twenty times less accurate, and entirely incapable of detecting a difference in speed of one part in a million. The results of these two independent investigations are therefore entirely consistent.

*Read by title.

M. Nordmann found that with Algol the minimum of the red rays occurred about sixteen minutes earlier than that of the blue rays, and about nine minutes earlier than that of the green, showing that, as in ordinary matter, the shorter waves are the most retarded.

The obvious objection to this is that the star should exhibit a change of color during its waning and waxing; but a sufficient answer to this is apparently to be found in the smallness of the effect detected by M. Nordmann and the great length (seven

Fig. 1.

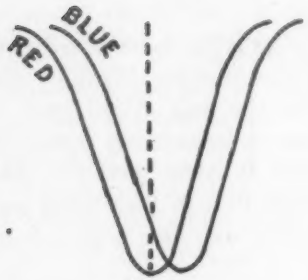


Fig. 2.

hours) of the period of variation of the star. Were the period of variation more brief and the light curve steeper, such an effect would doubtless be noticeable.

An inspection of Figs. 1 and 2 will make this clear. Fig. 1 is drawn to such a scale as to illustrate the proportionate shift of the red and blue light curves of Algol as found by M. Nordmann. It will be seen that at the red minimum the difference in intensity of the two colors is small. Fig. 2 is drawn for the same shift of minima, but a much shorter period, and it will be seen that there

is at the red minimum a much greater difference in the intensity of the two colors.

M. Nordmann has also applied his method to λ Tauri, another star of the Algol type, but fainter, and with a light curve less steep, the minimum remaining constant for about three hours. For this star he found a shift of the red and blue curves about three times as great as with Algol. Admitting the reality of this effect, it would appear that λ Tauri was at three times the distance of Algol.

Should M. Nordmann's results be confirmed by others it would by no means necessarily follow that the ether itself is a dispersive medium. M. Nordmann himself suggests the presence of dark nebulous masses scattered throughout space, and to which this slight dispersion may be due. And considering that the difference of one in a million represents a superior limit, and that owing to the uncertainty as to the parallax of Algol, the accuracy may be vastly higher, it would not seem an improbable hypothesis that the difference in speed may be due to a greater amplitude of the longer waves; that there may be in the ether an effect analogous to that in sound which causes a louder sound to travel slightly faster than a fainter one.

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

On Monday evening, April 27th, about seventy graduates of the schools of the Institute assembled in the hall for the purpose of forming an Alumni Association.

Mr. Walton Clark, President of the Institute, presided, and assured the meeting of his approval of its object, and his hearty cöoperation and that of the Board of Managers, and prophesied an interesting and important future for the association.

Mr. William H. Thorne, the Director of the Drawing School, spoke of the value of such an association, both to the graduates and to the Institute, and hoped that great care would be exercised at the beginning in the forming of the constitution and by-laws, and the selection of the officers, in order that permanency and success might be assured.

Mr. George S. Cullen, an old graduate and instructor, discussed eligibility for membership. Enthusiastic approval of the object was shown by the remarks of Messrs. Pedrick, Jones, Parsons, McCaffrey, Delaney, Fisher, Fennell and Davis, and Dr. W. H. Wahl, Secretary, and Mr. Henry Howson, Vice-President of the Institute.

On motion of Mr. Delaney, it was unanimously resolved that—It is the

sentiment of this meeting that an association of the students of the Franklin Institute be formed, and that the graduate students attendant at this meeting constitute themselves the charter members of such association.

On motion of Mr. Fennell, it was resolved that: A committee on constitution and by-laws be appointed by the President of the Institute, to consist of five members, and that Mr. Thorne be appointed chairman.

On motion of Mr. Fennell it was resolved that:

A committee of five be appointed by the President of the Institute to nominate permanent officers of the association.

The President appointed the following as the committee on constitution and by-laws: Messrs. Thorne, Parsons, Cullen, Jones and McCaffrey.

On motion, adjourned.

WM. H. THORNE, *Sec'y.*

THE FRANKLIN FUND.

The following item of interest relating to the "Franklin Fund" is contributed by Mr. Charles E. Ronaldson, member of the Board of Managers of the Institute, and a direct descendant of the James Ronaldson referred to in this note:

(Extract from the Autobiography of James Ronaldson, page 306.)

"It is interesting to note that the 'Franklin Fund' received an addition at the hands of John Scott, Chemist, living in St. Patrick's Square, Edinburgh, Scotland, who appointed James Ronaldson, of Philadelphia, Type Founder, as his true and lawful attorney for him and, in his name, as sole Executor to transfer the sum of 3000 Dollars of certain stock, to the Corporation of Philadelphia, which was entrusted with the management of the late Dr. Franklin's legacy, to be applied to the purposes of the legacy—"—From the Historical Catalogue of St. Andrew's Society, 1749-1907.

Book Notices.

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Circular 117, The Preservative Treatment of Fence Posts. By Howard F. Weiss. 15 pages, illustrations, 8vo.
Circular 127, Forest Tables—Western Yellow Pine. Compiled by E. A. Ziegler. 23 pages, 8vo.
Circular 128, Preservation of Piling Against Marine Wood Borers. By C. Stowell Smith. 15 pages, illustrations, 8vo.
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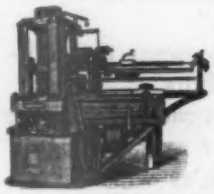

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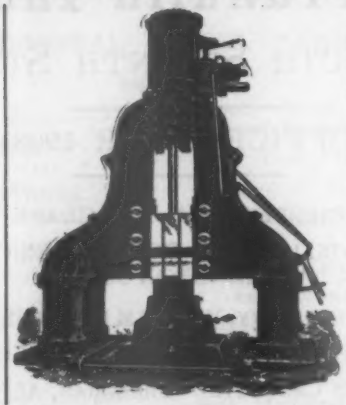

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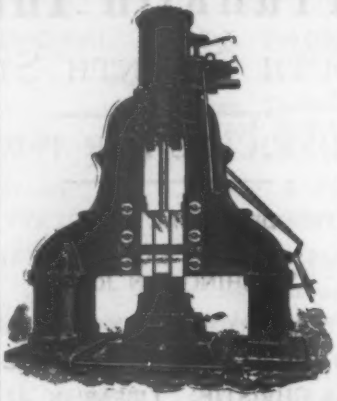

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